Rio Blanco Oil Shale Project

DETAILED DEVELOPMENT PLAN
TRACT C-a

VOLUME 2

BASELINE CONDITIONS
(Book 2 of 2)

Gulf Oil Corporation . Standard Oil Company(Indiana)

March, 1976

RIO BLANCO OIL SHALE PROJECT

DETAILED DEVELOPMENT PLAN

TRACT C-a

VOLUME 2

SECTION 3 BASELINE CONDITIONS

(Book 2 of 2)

(Chapters 7 thru 14)

Submitted To Area Oil Shale Supervisor,
Geological Survey, U.S. Department of
the Interior, Pursuant To Lease No. C-20046

Gulf Oil Corporation - Standard Oil Company (Indiana)

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DDP ABSTRACT

In 1969, the U.S. Department of the Interior initiated planning for a prototype oil shale leasing program that eventually resulted in Gulf Oil Corporation and Standard Oil Company (Indiana) acquiring an oil shale lease for Tract C-a in the Piceance Creek basin of northwest Colorado. Gulf and Standard submitted the high bonus bid for Tract C-a ($210,305,600) at a lease sale in Denver on January 8, 1974. Rio Blanco Oil Shale Project (RBOSP) an organization directed and staffed by representatives of Gulf and Standard, was formed later that year for the purpose of developing Tract C-a.

In the past two years, RBOSP has conducted extensive geotechnical and environmental data collection programs designed to establish baseline conditions on and around Tract C-a and to provide input to engineering studies leading to the selection of mining and processing plans for Tract C-a development. This 4-volume detailed development plan (DDP) describes the baseline conditions and RBOSP's proposed construction and operation of a commercial-scale oil shale complex and support facilities on and around Tract C-a. Three major requirements must be met before development operations on Tract C-a can begin:

- The Area Oil Shale Supervisor, U.S. Geological Survey, must approve the development plan.
- Key Federal and State actions must be fulfilled and permits issued.
- The proposed development described in this plan must be commercially feasible at the time investments are committed.

PROJECT DESCRIPTION

RBOSP's ultimate goal with respect to Tract C-a development is to engage in commercial production of shale oil and associated by-products at as high a production rate as is feasible, consistent with environmental, technical and economic constraints that now prevail or may exist in the future.

Development will consist of open pit mining, off-tract surface retorting, and off-tract disposal of processed shale and overburden, and will be undertaken in two operating phases, each preceded by three-year construction periods. Phase I operation will consist of two stages, wherein first one, then two retort modules will be operated. This modular approach will provide RBOSP the opportunity to gain operating experience, improve process efficiency and confirm capital and operating costs before a full-scale oil shale complex is built. Phase II will be the commercial-scale complex. Table 1 is a summary of information pertinent to RBOSP's proposed development of Tract C-a. Figure 1 depicts the location of proposed RBOSP facilities.

Phase I - Stage 1 operations will begin during 1979 with a small open pit mine and a single TOSCO II retort capable of processing 10,700 tons of oil shale per day to produce approximately 4,500 barrels of pipelineable shale oil daily. Phase I - Stage 1 will include a thermal cracking plant for lowering the viscosity and pourpoint of raw shale oil so that it can be transported by pipeline. A sulfur recovery unit will also be included.

TABLE 1

RIO BLANCO PROJECT SUMMARY

	PHASE I		
	Stage I	Stage 2	PHASE II
TIMING			
Construction	Apr. 1977-Aug. 1979	July 1980-Aug. 1982	Aug. 1982-Aug. 1985
Operation	Aug. 1979-Aug. 1982	Aug. 1982-Aug. 1985	Aug. 1985 and beyond
MINING			
Type	Open Pit	Open Pit	Open Pit
Ore Production	10,700 TPSD	21,400 TPSD	119,000 TPSD
Ore Haulage	Belt Conveyor	Belt Conveyor	Belt Conveyor
Overburden Haulage	Truck	Truck	Belt Conveyor
PROCESSING			
Retorting	TOSCO II	TOSCO II	Combination of TOSCO II & Gas Combustion/Paraho
Upgrading	Thermal Cracking	Thermal Cracking	Delayed Coking & Hydrotreating
Processed Shale Haulage	Truck	Truck	Belt Conveyor
PRODUCTS			
Pipelineable Shale Oil	4,500 BPSD	9,000 BPSD	-
Upgraded Shale Oil	-	-	55,800 BPSD
Sulfur	11 LTPSD	22 LTPSD	153 LTPSD
Ammonia (anhydrous)	-	-	232 TPSD
Coke	-	-	467 TPSD
Moisturized Processed Shale	11,000 TPSD	22,000 TPSD	118,500 TPSD
WATER DEMAND	1,390 AFY	2,370 AFY	10,000 AFY
POWER DEMAND	17.7 MW	28.8 MW	227 MW
PEAK EMPLOYMENT			
Construction	700	400	2,200
Operation	300	500	1,100

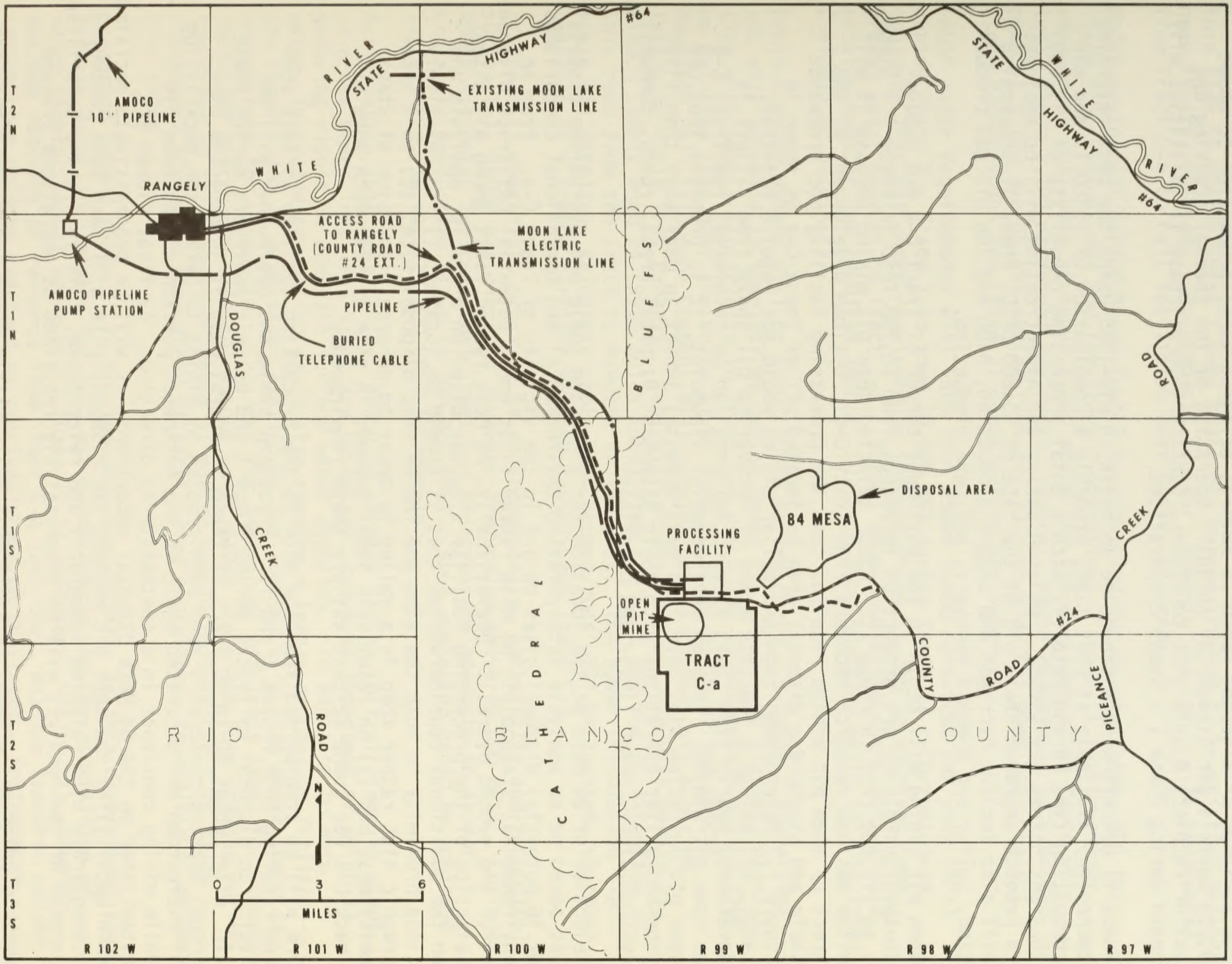

Figure 1

LOCATION OF PROPOSED RBOSP FACILITIES

Phase I - Stage 2 operations will begin three years later, during 1982, with the addition of a second TOSCO II retort, bringing total production to about 9,000 barrels per stream day (BPSD). Operation of the thermal cracking and sulfur recovery plants will continue. Construction of Phase II facilities will begin during Phase I - Stage 2 operations.

Phase II operations are scheduled to begin in mid-1985 using the best retorting technology available at that time, probably a combination of TOSCO II and gas combustion-type Paraho retorts, with a total processing capability of 119,000 tons per stream day (TPSD). Delayed coking and hydrotreating will be employed to produce upgraded shale oil at the rate of 55,800 BPSD. Phase II processing will also include hydrogen and oxygen production, high and low BTU gas production, sulfur and ammonia recovery, and coke production.

Open pit mining will begin in the northwest corner of Tract C-a and expand southeastwardly as ore production increases from 10,700 TPSD in Phase I - Stage 1 to 119,000 TPSD in Phase II. RBOSP selected open pit mining because it will allow maximum resource recovery from Tract C-a. Optimum development of the tract by open pit mining requires that the processing facility and processed shale and overburden disposal area be located off of Tract C-a as shown in Figure 1. Underground room-and-pillar mining would not require off-tract lands, but unless a feasible means of recovering oil shale from pillars is developed, nearly five times as much resource can be recovered from Tract C-a by open pit mining. From an environmental viewpoint, it is probable that one open pit operation will have less environmental impact in many ways than five room-and-pillar operations with their attendant disposal areas, roads, communications lines, power lines, and pipelines.

Selection of 84 Mesa as the location for processed shale and overburden disposal was based on an analysis incorporating environmental and operational comparisons of 16 potential disposal sites on and in the vicinity of Tract C-a. From an environmental standpoint, 84 Mesa ranked first among potential off-tract disposal sites and second overall. Operationally, 84 Mesa ranked first among all sites. Selection of the processing facility site was based on a similar analysis and on the additional considerations that it should be located: (1) in relatively close proximity to both the mine and the 84 Mesa disposal site; (2) on a topographic high rather than in a valley in order to enhance dispersion of stack emissions; and (3) on relatively level ground. A site at the north edge of Tract C-a was found to best satisfy these requirements.

Ore will be transported from the mine to the processing facility by belt conveyor during both Phases I and II. Processed shale and overburden will be hauled to disposal by trucks during Phase I and by belt conveyors during Phase II. After about 30 to 40 years of Phase II operations, it is expected that enough working space will have been created by mining to permit the backfilling of overburden and processed shale in the northwest portion of the open pit while mining continues in a southeasterly direction. As final slopes are established on the 84 Mesa disposal embankment, it will be progressively reclaimed. When backfilling the open pit begins, the disposal pile will have been contoured commensurate with existing topography and revegetated. Similarly, the backfilled portion of the open pit will be progressively reclaimed as operations proceed.

RBOSP's principal product (pipelineable shale oil in Phase I and upgraded shale oil in Phase II) will be transported by pipeline to Rangely, Colorado,

thence through an existing AMOCO pipeline to other connecting carriers for ultimate delivery to refineries in the West or Midwest; a possible exception to this plan is during Phase I when shale oil may be trucked to an existing refinery near Fruita, Colorado. By-products (sulfur, ammonia and coke) will be trucked from Tract C-a to rail facilities near Rifle, Colorado.

RBOSP employment during Phase I will be about 700 for construction, 300 for Stage 1 operations and 500 for Stage 2 operations. Phase II construction employment will peak at about 2,200 while the Phase II operating force will total about 1,100 permanent employees. Overall RBOSP employment is expected to peak at 2,700 during the period from mid-1982 to mid-1985 when both Phase I - Stage 2 operations and Phase II construction are underway.

RBOSP water requirements will vary from about 1,400 acre-feet per year (AFY) during Phase I - Stage 1 to some 10,000 AFY during Phase II. Current data indicate that all water requirements through Phase II can be supplied from ground water sources on Tract C-a. Normal mine dewatering operations should provide most of the required amount, but some supplementary wells (all on Tract C-a) may be necessary.

Project power demand will be about 18 MW during Phase I - Stage 1 operations and will increase to some 227 MW during Phase II. Moon Lake Electric Association will supply electricity to Tract C-a via a 230-KV transmission line from an existing line near the White River some 20 miles north of the tract. Mountain Bell Telephone Company will provide communications via a buried telephone cable from Rangely. Vehicular access to Tract C-a will be via Rio Blanco County Road 24 (Ryan Gulch Road) from the east and via an extension of this road from the tract to Rangely on the west. The power tranmission line, shale oil pipeline, telephone cable, and access road will be located, wherever possible in a common corridor between Rangely and Tract C-a.

If Phase II operations prove to be environmentally, technically and economically successful, RBOSP may elect to increase production above 55,800 BPSD. Current RBOSP estimates indicate that Tract C-a reserves are adequate to support a shale oil production of up to 300,000 BPSD. Such expansion could be achieved, for example, in two-125,000 BPSD increments.

Anticipating this possibility, RBOSP is already taking initial planning steps in areas where long lead times are necessary, the most important of which is securing rights to adequate surface water supplies. In addition to more water, increased production would also require a larger processing facility -- the Phase I and II processing facilities are located at a site where there is enough room for expansion. The need for additional off-tract lands for processed shale and overburden disposal is not anticipated since the void created during the first 30 to 40 years of Phase II mining should be sufficient to allow subsequent mining to stay ahead of backfilling operations, regardless of production rates.

Expansion beyond Phase II is treated only conceptually in this development plan because detailed planning for such expansion (excepting the acquisition of water rights) cannot begin until Phase II is underway. Ultimately, however, maximum recovery of resource from Tract C-a (and thus, maximum resource conservation) can only be realized by completely mining the tract. Furthermore, leaving exposed mining faces at the south and east boundaries of Tract

C-a will permit future developers on adjacent leases to continue open pit mining where RBOSP operations end.

BASELINE ENVIRONMENTAL AND GEOTECHNICAL CONDITIONS

As noted earlier, RBOSP has initiated extensive geotechnical and environmental baseline data collection programs on and around Tract C-a. These programs are designed to obtain data needed for engineering studies and development plans as well as fulfilling specific lease requirements.

Geotechnical data collection is subdivided into geologic and hydrologic programs. The geologic program is designed to provide detailed topographic, structural, stratigraphic, and resource data. The hydrologic program will provide data for determining baseline hydrologic conditions, aquifer characteristics, and for predicting the quantity of water expected to be produced during open pit mining.

The baseline environmental program designed by RBOSP complies with lease stipulations and, in addition, reflects the following goals: (1) to identify any potential data gaps that might exist in the lease stipulations and develop programs to correct such oversights; and (2) to evaluate lease stipulations and, if appropriate, suggest amendments that would best serve the environmental spirit enunciated in the lease.

The baseline environmental program was approved by the Area Oil Shale Supervisor following review and recommendations by the Oil Shale Environmental Advisory Panel. The program includes data collection in the following disciplines: air quality, meteorology, terrestrial and aquatic ecology, soil characterization, archaeology, and paleontology. Data from all elements are combined to describe overall ecological interactions. Incorporated in the design of these programs is a flexibility allowing response to changes indicated by the constantly expanding data base, without altering original objectives. For example, the study area in some programs was expanded from the original design to ensure coverage of potential disposal and processing facility sites. In addition to characterizing the physical and biological components of the Tract C-a study area, both qualitatively and quantitatively, the baseline environmental program will yield data for designing a monitoring program to measure changes caused by development.

ENVIRONMENTAL PROTECTION

RBOSP has developed specific environmental protection procedures to ensure compliance with lease provisions and environmental stipulations, and with all applicable Federal, State and local environmental protection and pollution control regulations. These procedures, or mitigation plans, are designed specifically for RBOSP's intended development of Tract C-a and will be modified, if necessary, as changing conditions are noted. The protection procedures described in this development plan cover the following topics:

Health and Safety
Air Quality Control
Water Quality Control
Solid Waste Control
Noise Control
Aesthetics
Abandonment
Fish and Wildlife Management
Land Rehabilitation
Oil and Hazardous Materials Control
Fire Prevention and Control
Protection of Objects of Historic and Scientific Interest

RBOSP has conducted an environmental assessment of proposed Tract C-a development. This assessment was based on the fact that the protection plans listed above will be implemented and that they will be modified as conditions dictate. The results of this assessment are that Tract C-a development alone will have slight, if any, impact on the functioning of the overall Piceance Creek basin ecosystem.

Various environmental monitoring programs will be conducted to provide a record of changes from conditions existing prior to development as established by the baseline data collection program, and to serve as a continuous check on compliance with lease provisions and applicable Federal, State and local environmental protection and pollution control regulations. Programs have been designed to monitor air quality, meteorology, hydrology, terrestrial and aquatic ecology, and revegetated areas. Analysis of data collected during the baseline program provides the basis for selecting those parameters that will most effectively indicate detrimental effects and, thus, the necessity for taking corrective action such as altering one of the environmental protection plans.

The monitoring programs will be initiated six months before development begins on Tract C-a. Monitoring will continue until the Area Oil Shale Supervisor determines to his satisfaction that environmental conditions consistent with Federal and State statutes and regulations have been established.

SOCIO-ECONOMIC PLANNING

Gulf and Standard recognized the potential social and economic impacts of oil shale development when the Tract C-a lease was acquired in January 1974. The two companies pledged then to cooperate with, support and participate in regional planning with the communities affected and with local, county, state and Federal governmental agencies.

A socio-economic plan is not legally required by the Tract C-a lease, but RBOSP officials and the Area Oil Shale Supervisor feel that such a plan is desirable. The overall objectives of RBOSP's socio-economic planning activities are to reduce negative impacts and to avoid the mistakes and resulting problems encountered in other areas experiencing significant population increases caused by new industry. RBOSP's plan to achieve these goals is described in a socio-economic report submitted separately from the detailed development plan.

STATE AND FEDERAL ACTIONS NEEDED BEFORE RBOSP CAN PROCEED

A variety of state and Federal actions are necessary before RBOSP can implement development of Tract C-a as described in this document. Specific actions needed are as follow:

- Area Oil Shale Supervisor approval of the detailed development plan
- Bureau of Land Management issuance of right-of-way permits for
    - pipeline to Rangely
    - road to Rangely
    - power transmission line
    - telephone cable
- BLM approval of use of 84 Mesa for disposal area
- BLM approval of use of offsite lands for processing facility
- Townsite lands are made available to Rangely by the BLM
- State appropriation for and construction of access roads
- State legislation to enable a town to receive and administer townsite lands
- An acceptable land trade with State Division of Wildlife for surface lands on and around Tract C-a
- State reclassification of air quality designation for area on and around Tract C-a
- Issuance of all required State and Federal permits

DDP ORGANIZATION AND USE

RBOSP's DDP consists of 11 sections comprising four volumes, as depicted in the chart on page 9. Volume 1 includes sections entitled "Project Background" and "Executive Summary." If one is interested in an overview of the development plan, Volume 1 is recommended.

Volume 2 is the largest of the four volumes. It describes baseline geological, hydrological and environmental conditions on and around Tract C-a. Volume 3 describes engineering plans for developing Tract C-a and includes sections on mining, retort feed preparation, processing, processed shale and overburden disposal and support facilities. Volume 4 describes RBOSP's environmental protection plans and also includes sections concerning environmental assessment and monitoring. The Confidential Volume, which is not publicly available, contains proprietary information concerning oil shale properties and ore reserve and cost estimates.

Except for the DDP abstract, a 3-number page numbering system is used throughout the development plan. Any given page number is unique in that it is not repeated elsewhere in the DDP. Page numbers are keyed to chapters within sections; page 3-4-45, for example refers to the 45th page of Chapter 4, (Hydrology) of Section 3 (Baseline Conditions).

RIO BLANCO OIL SHALE PROJECT
DETAILED DEVELOPMENT PLAN ORGANIZATION

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7 PROCESSED SHALE & OVERBURDEN DISPOSAL
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9 ENVIRONMENTAL PROTECTION, HEALTH & SAFETY
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BASELINE CONDITIONS

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CHAPTER 7

TERRESTRIAL ECOLOGY

SECTION 3

BASELINE CONDITIONS

CHAPTER 7

TERRESTRIAL ECOLOGY

Terrestrial ecological sampling took place between October 1974 and October 1975 on Tract C-a and on areas within a radius of five miles around Tract C-a. The objectives stated in this report for each program under terrestrial ecology do not, in many cases, agree with those stated in the Scope of Work for terrestrial investigations (May 1975) because that Scope of Work is tailored to a two-year baseline program; hence some of the objectives of the two-year study have not yet been met. Figures presented in the text have been rounded in many cases. All figures presented are not absolute. For the ranges of figures presented in the text, refer to the Second Annual Report (RBOSP. 1976).

7.1 FLORA

A. Phytosociological Studies

1. Objectives - The objectives of vegetation investigations in the vicinity of Tract C-a are to identify the plant species present (floristics), define the structural and compositional organization of these species in recognizable associations (phytosociology), and to correlate floristics and phytosociology with the biotic and abiotic environment (ecology).

2. Methods

a. Data Collection - Aerial photographs and pertinent literature were used to identify the major vegetation types on and adjacent to Tract C-a. A vegetation type is recognized by the presence and life form of the dominant overstory plant species. Understory vegetation is not considered in type designations.

Each representative of a type selected (such as pinyon-juniper) was then surveyed on the ground and the most prevalent associations (variants) of the overall type (for example., pinyon-juniper with a sagebrush understory) were identified. The largest block of homogeneous vegetation of each association was selected for sampling.

A modification of the line-strip technique as described by Woodin and Lindsey (1954), Lindsey (1955), and Potter (1957) was used during the phytosociological investigations.

See pages 3-7-2 through 3-7-9 of the Second Annual Report (RBOSP, 1976) for detailed methodology used in phytosociological sampling.

b. Data Analysis - The following species parameters were estimated from phytosociological data collected for mature tree, shrub-tree seedling, and herbaceous strata sampled on permanent and/or non-permanent transects:

- % cover - average % canopy cover of a species.
- Cover (m^2 per unit area) - an estimate of the number of square meters per a specified area (e.g., hectare) covered by the canopy of a species.
- Shrub volume - volume of visualized, hypothetical sphere enclosing the shrub canopy.
- Frequency (%) - the % of sampling units within a transect that include a species.
- Constancy - the % of transects within a type that include a species.
- Density - number of individuals of a species per unit area (e.g., #/ha) expressed as average #/quadrat for herbaceous species.
- Basal area (m^2 per unit area) - an estimate of the area in square meters of the trunks of a tree species per a specified unit area (e.g., hectare). The area of a trunk is determined from the formula $\pi d^2/4$, when d is the trunk diameter at a specified point.
- Sociability - density (#/quadrat) divided by the frequency. An index to the pattern of herbaceous species distribution.

For specific formulae used in calculation of phytosociological parameters see pages 3-7-8 and 3-7-9 of the Second Annual Report (RBOSP, 1976).

3. Data Summary - For specific results of phytosociological studies conducted in all vegetation types and associations refer to pages 3-7-16 through 3-7-51 of the Second Annual Report (RBOSP, 1976). Conclusions and highlights of those results are discussed in the following sections.

a. Climate - The elevation of the Tract C-a study area ranges from a low of 1,890 m (6,200 ft) at the junction of Duck Creek and Yellow Creek to a high of 2,644 m (8,675 ft) on Cathedral Bluffs near the headwaters of Spruce Gulch. The climate of the area is classified as arid steppe and is characterized by abundant sunshine during all seasons, insufficient precipitation for vigorous vegetative growth, warm summer temperatures and low relative humidity (Marlatt, 1973).

The scarcity of precipitation, hot summers and incidence of thunderstorms has been conducive to fires from lightning and human carelessness. The incidence of fire was noted most commonly in the pinyon-juniper type, but was also evident in some Douglas fir stands. Precipitation in the Piceance Basin ranges from 28 cm (11 in.) in the northwest corner to 64 cm (25 in.) on the Roan Plateau. The major portion of the Piceance Basin receives 36 to 38 cm (1.4 to 15 in.) of precipitation, with about equal monthly distribution (Terwilliger, 1973).

b. Soils - The soils of the study area are part of the plateau land type within the Piceance Basin and are primarily formed in place except for the alluvial deposits found in most of the drainages. The plateau soils are generally shallow sandy loams that range in depth from almost zero on rock outcrops to more than 61 cm (24 in) under dense aspen stands.

c. Floristics - The flora identified in the Tract C-a study area during 1974-1975 included five tree species, 36 shrub species, and 168 herbaceous species, of which 44 species are classified as grass or grass-like. Three species included in the flora require special notation. A milkvetch, *Astragalus*

lutosus, is on the Smithsonian Institution endangered plant species list (Smithsonian Institution, 1975) and was located near Cottonwood Spring on Big Duck Creek. *Aquilegia barnebyi*, a columbine endemic to the Green River formation (Munz, 1949), was located near Cottonwood Spring on Big Duck Creek. Colorado columbine, *Aquilegia caerulea*, (Harrington, 1964) is the state flower and was located in most of the aspen stands and some of the more mesic mixed brush and Douglas fir stands near Cathedral Bluffs.

d. *Phytogeography* - The dominant species of the Tract C-a vicinity flora form a mosaic of plant associations representative of two major vegetation formations: the cold desert formation (Ootsing, 1956), dominated by big sagebrush (*Artemisia tridentata*), shadscale (*Atriplex confertifolia*), and black greasewood (*Sarcobatus vermiculatus*); and the needle-leaved forest formation of the Rocky Mountain forest complex (Daubenmire, 1943), dominated by Douglas fir (*Pseudotsuga menziesii*), quaking aspen (*Populus tremuloides*), Utah serviceberry (*Amelanchier utahensis*), pinyon pine (*Pinus edulis*), and Utah juniper (*Juniperus osteosperma*). The mosaic of plants within these major formations is the result of the differing ecological amplitudes of the dominant species and the alteration of climatic and edaphic gradients created by the diverse topography (Vories, 1974).

e. *Abiotic Factors Affecting Plant Distribution* - Vegetation development in the study area is primarily affected by its relationship to the following factors: the overall climatic regime, elevational gradient, topography, geology, and soil development.

Aspects of the climatic regime of critical importance to plants are distribution and amount of rainfall and snowfall, length of the growing season, maximum and minimum temperatures for a given area, and the frequency and velocity of wind. Available soil moisture is a major determining factor in plant distribution in this region. Temperature and wind affect the water evaporation rate from soil, which affects moisture availability to plants. Length of growing season, and maximum and minimum temperatures define limits within which plant species must be physiologically tolerant, and capable of reproduction. Wind is also important in defining snowdrift patterns which affect soil moisture.

An increase in elevation has the general effect of increasing precipitation, decreasing temperature and decreasing soil pH (Daubenmire, 1943). The elevation gradient is particularly evident in the study area, with a rise in elevation (approximately 762 m [2,500 ft]) from the floor of the Piceance Basin to the summit of Cathedral Bluffs on the western perimeter of the Basin.

Variations in topography affect the amount of sunlight striking different slopes. The steepness of slope affects the angle with which the sun's rays strike the slope, and the direction of slope affects the duration of sunshine on a slope. North-facing slopes are cooler and wetter than all other slope aspects, and south-facing slopes are drier and hotter. East and west-facing slopes are intermediate in temperature and moisture, with east-facing slopes being cooler and wetter than west-facing slopes. This is caused by the higher air temperatures prevalent during exposure to the afternoon sun. Because of these topographic modifications, plant associations from a lower, drier vegetation zone may be found on generally south-facing slopes in a higher zone, and plant associations from a higher, wetter zone may be found on the north-facing slope of a lower zone.

The geology of an area largely determines the types of soil that develop. Physical properties of soils determine aeration and moisture-holding capacity, and chemical properties are important in determining the availability of nutrients and water to plants. Soil depth is important in determining moisture availability. Location of the water table affects the distribution of plant species, particularly along alluvial stream bottoms.

f. Biotic Factors Affecting Plant Distribution - The effects of wildlife and terrestrial invertebrates on vegetation composition and structure are developed in detail in other parts of this report and are mentioned here to indicate their importance in determining vegetation distribution and overall vegetation development.

At the lower elevations, shrub and tree species are selectively browsed by mule deer, resulting in a localized alteration of plant species composition and structure. Desirable plants, such as mountain mahogany, are heavily pruned, frequently releasing undesirable species from competition.

At the higher elevations within the pinyon-juniper woodland, the girdling of pinyon trunks by porcupines is common. Boring beetle infestations on pinyon pine, galls on Utah juniper, and tent caterpillars on Utah serviceberry and mountain mahogany were observed to produce a localized loss of production and plant vigor.

The historic effects of man on the vegetation of the study area include the removal of sagebrush from bottomland areas and the introduction of livestock and exotic plant species. The response of the native vegetation has been an alteration of community composition and structure due to the selective grazing pressures of livestock, and the invasion of exotic plant species on disturbed sites.

g. Vegetation Types - The figures presented in this section are not absolute. The ranges of these figures are presented in the Second Annual Report.

1) Aspen - The aspen type on the study area was characterized by the constant presence of aspen, and dense and diverse shrub and herbaceous strata, consisting primarily of serviceberry in the shrub stratum, and elk sedge (*Carex geyeri*) in the herbaceous stratum. The type ranged in elevation from 2,418-2,609 m (8,140-8,560 ft) on steep, north and east-facing slopes. The soils were generally deep sandy loams with large accumulations of organic matter.

The type is bordered at the higher elevations by the Douglas-fir type and at lower elevations by the mixed brush type. A few seedlings of Douglas-fir were found in areas where the aspen and Douglas-fir type bordered each other. Although aspen often precedes Douglas fir in succession, the low presence and reproductive success of Douglas fir in aspen stands indicated that most stands were not being replaced by Douglas fir in the study area. The large number of aspen saplings and lack of mature trees in size classes greater than 24 cm (9.4 in) indicated a relatively high mortality rate and rapid turnover of individuals within the aspen population. This observation agrees with tree core samples collected by Vories (1974) in the same area which showed 67% of the aspen to be under 15 cm (6 in) in diameter and less than 48 years old. Only 1% of the aspen trees were above 30 cm (12 in) in diameter and over 64 years old. Also noted was the high incidence of heart rot in the larger size classes of quaking aspen.

Aspen reproduction by seeds is very rare, and nearly all populations are clonal (sharing a common root system which sends up individual stems). Despite the short life span of individual trunks, the substantial resprouting observed in nearly all stands sampled indicates that most aspen stands within the study area are presently self-sustaining.

The diverse (14 species) shrub stratum was dominated by Saskatoon serviceberry (Amelanchier alnifolia) and Utah serviceberry. These species provided 19% and 14% cover, respectively. Common black chokecherry (Prunus virginiana, 12% cover) was also present. Mountain snowberry (Symphoricarpos oreophilus) was common as a low shrub and may dominate in more open stands, especially near the forest edge. Species such as Rocky Mountain maple (Acer glabrum) and Greene's mountain ash (Sorbus scopulina) were found in the moist sites.

Phenology data indicate that the dominant shrub species, serviceberry, and chokecherry, bloom in the spring, and produce ripening fruits by July. Common understory plants such as snowberry and Wood's rose (Rosa woodsii) bloomed in July, indicating a sustained period of flowering within the shrub stratum of this type, which may reflect a long period of available moisture.

Forbs characteristic of the summer growth included Canada violet (Viola canadensis), mountain thermopsis (Thermopsis montana), sweet root (Osmorhiza depauperata), and northern bedstraw (Galium boreale). Elk sedge achieved its highest cover values in the fall (6%) while most of the forb species decreased in total cover. Low goldenrod (Solidago multiradiata) did not account for a large portion of the total cover (2% in July and 1% in September) but was strikingly noticeable in aspen stands of the study area because of its height.

The margins of the aspen stands were relatively open and grazed by livestock. The interior of the stands were steep and tangled by shrubs and fallen trees with no indication of livestock grazing.

2) Douglas fir - The Douglas fir type was characterized by the constant presence of Douglas fir, and a dense and diverse shrub stratum. The herbaceous stratum was dominated by elk sedge. The douglas fir type was restricted to higher elevations in the study area near the summit of Cathedral Bluffs, occurring on steep north and east-facing slopes. Douglas fir dominated the tree stratum, providing nearly 100% relative cover, and occurred at densities of approximately 500 individuals per hectare. Uniform distribution of trees in the mature size class, and a very large percentage of all trees occurring in the smallest size class, indicate that Douglas fir was actively reproducing, but also had a high seedling mortality.

The shrub stratum in the Douglas fir type consisted of two layers. The upper layer was dominated by Utah serviceberry, which occurred in large clones, and ranged in height to 3 m (10 ft). The lower layer was dominated by mountain snowberry, which occurred at high densities and was usually less than 1 m (3.3 ft) in height. Together, the two species provided 42% of the total cover, and 46% of the total density. Both species were leafing out in May-June of 1975, and snowberry was flowering and serviceberry was forming fruits in July, 1975. Both species were recorded as vegetative in September, 1975.

Herbaceous species diversity and total cover was lower than in aspen stands at comparable elevations, indicating that Douglas fir may exert a greater limiting influence on the herbaceous stratum than aspen. Elk sedge was the dominant species during all sampling periods, providing relatively constant cover of approximately 10% throughout the year. Maximum cover and species diversity occurred during July, when 23 species provided 23% total cover. Approximately 80% of the same species were present during sequential sampling periods. The dominant species, elk sedge, flowers in late spring shortly after snowmelt.

3) Mixed Brush - The mixed brush type was characterized by the tall shrub life form of three species, Gambel oak, Utah serviceberry, and true mountain mahogany. The type occurred over an elevational range of 2,179-2,621 m (7,150-8,600 ft). The type occurred on a wide range of slopes from steep to gentle, and at all slope aspects. The best shrub development occurred on the steep

north and east-facing slopes within the type. The soils associated with this type were shallow to moderately deep, well-drained sandy loams.

The mixed brush type intergraded with the aspen and Douglas fir types on steep slopes at the upper elevations, and on the more gentle upland slopes and ridges it integraded with the sagebrush type. At the lower elevations the mixed brush type gradually intergraded with the sagebrush type or existed as islands on steep north-facing slopes within the pinyon-juniper type.

The shrub stratum showed a wide range of diversity with up to 20 species, and was divided into a tall shrub layer domianted by Utah serviceberry (52% relative cover) and a low shrub layer dominated by big sagebrush or mountain snowberry. Gambel oak increased in importance in the wetter stands and true mountain mahogany increased in importance on the drier slopes or shale outcroppings. Phenology data indicate that the dominant shrub species, Utah serviceberry and Gambel oak, flower during the spring; snowberry flowers during mid-summer; and composite species such as big sagebrush and rabbitbrush (Chrysothamnus sp.) flower in the fall.

In the spring, elk sedge was the only dominant species, providing over 2% cover out of the total cover of 5%. Total cover increased to 11% in July, and declined to 8% in September, 1975. In September 1975, elk sedge was the only species contributing over 1% cover.

The mixed brush type is represented by two plant associations in the study area. The Utah Serviceberry-Gambel oak association is distinguished by the presence of Gambel oak and a dense shrub stratum. Ordination of transects sampled in this association by elevation and slope indicates the narrow elevational range of this association, and its restriction to cool, steep slopes.

The clonal nature of both Utah serviceberry and Gambel oak as well as their dense cover (39% and 13% cover, respectively) produced an almost impenetrable thicket. Mountain snowberry was found in abundance in the openings between the taller shrubs and beneath serviceberry plants. Common black chokecherry

and Saskatoon serviceberry were found in the wettest stands within the association. Big sagebrush (8% cover) was found commonly in more open stands and near the edges of the stands.

The herbaceous stratum was relatively well-developed (maximum of 26% cover), and dominated by elk sedge.

The second mixed shrub association is the Utah serviceberry-mountain snowberry association. This association is distinguished by dispersed, large Utah serviceberry plants (26% cover) interspersed by mountain snowberry (12% cover). It is found on dry, low elevation slopes within the mixed brush type. Elevations averaged approximately 92 m (300 ft) less than elevations for the previous mixed brush association. The elevational ranges of the two associations nearly overlap in the study area. This association occurred on gentle slopes and at all slope aspects, although it was predominantly encountered on north and east-facing slopes.

Big sagebrush (8% cover) was common in the openings among the large Utah serviceberry plants. True mountain mahogany was found in the driest stands, usually on shale outcroppings. Other species indicative of dry sites include horsebrush (Tetradymia canescens) , pinyon pine, Utah juniper and prickly pear (Opuntia polyacantha). The presence of pinyon pine and Utah juniper in the shrub stratum, in addition to the scarred stumps of these two tree species in some of the stands of this association, indicated successional relationships and competition between shrub species and pinyon and juniper.

The herbaceous layer was characterized largely by drought-resistant grasses and forbs. The plants tended to be well spaced with no clearly dominant or constant species.

4) Pinyon-Juniper - The most extensive vegetation type in the Piceance Basin and the study area is dominated by pinyon pine and Utah juniper.

In the Piceance Basin, the pinyon-juniper type is completely overlapped in elevation range [1,859-2,400 m (6,100-7,875 ft)] by the sagebrush type [1,821-2,682 m (5,975-8,800 ft)]. In the study area, the pinyon-juniper type was sampled over an elevational range of 1,981-2,335 m (6,500-7,660 ft).

Pinyon-juniper and sagebrush are segregated by the differing abilities of the dominant species to compete with each other under differing soil conditions. Sagebrush occupies the valleys, mesas, or gentle slopes where fine-textured, deep soils are prevalent. Pinyon-juniper occupies the ridges, canyons, or steep slopes where coarse rocky soils predominate. On soils intermediate in texture and depth there is a great deal of competition between sagebrush, pinyon pine, and juniper. The pinyon-juniper type also interacts with the mixed brush type, which occupies slopes where snow accumulates in winter within the elevation range of the pinyon-juniper type (Woodbury, 1947).

Vegetation transects were not placed relative to soil type, however, within boundaries extending one mile from the Tract C-a border, 75% of the randomly placed pinyon-juniper transects sampled during 1975 occupied shallow, well-drained soils formed from sandstone on steep to gentle upland slopes and ridges. Thirteen percent of the transects occurred on steep rock outcrop areas on south-facing slopes along major drainages. Eight percent of the transects occurred on soils originating from calcareous sandstone, and 4% occurred on moderately deep, well-drained soils formed from sandstone and windblown materials. The pinyon-juniper type was found on all slope aspects and showed no significant preference for any particular aspect.

The tree canopy of pinyon and Utah juniper in the study area was usually very open (21% total cover), with the individual trees well spaced (250 individuals/ha). The density of individual stands has been observed by Woodbury (1947) to increase with the increased available moisture at higher elevations. Woodbury also noted the tendency for juniper to be more prevalent on drier sites at lower elevations and pinyon to be more prevalent on wetter sites at higher elevations. The higher basal area for Utah juniper (23 m^2/ha) versus that for

pinyon (14 m^2/ha) indicated the generally larger trunk size and probable greater age of Utah juniper on the study area.

Ordination of shrub and tree cover for the pinyon-juniper type against elevation showed that tree cover of these two species increased to a maximum near 2,200 m (approximately 7,260 ft) elevation, and then declined above this point. Shrub stratum cover showed an inverse pattern, providing greatest cover at the lower and higher extremes of the range of the two dominant tree species. Big sagebrush, in particular, increased in cover at the elevational extremes of the pinyon-juniper type.

The shrub stratum was diverse (17 species) but maintained a low average cover (11%). The shrub cover has been noted to increase with increasing available moisture and the removal of the tree canopy by fire or chaining. As indicated above, the shrub cover decreased with the increasing maturity of the tree species and reduction of available moisture by evaporation. The most constant shrub within the type was big sagebrush. Seedlings and saplings of pinyon were common in the shrub stratum. Utah serviceberry was moderately frequent (40%) in the type and maintained a comparatively high cover (40%).

The herbaceous stratum was characterized by a high diversity (66 species), low total cover (2-6%) and the predominance of three grass species, slender wheatgrass (Agropyron trachycaulum), Sandberg bluegrass (Poa sandbergii) and Indian ricegrass (Oryzopsis hymenoides). Seasonal changes in cover were minimal and ranged from 2% in May-June to 6% in July, and 4% in September. No species contributed more than 0.5% cover in May-June. Three species, Agropyron trachycaulum, Poa sandbergii, and Oryzopsis hymenoides, contributed over 0.5% cover in July, while only Agropyron trachycaulum and Poa sandbergii contributed over 0.5% cover in September. The lack of herbaceous cover can be the result of several factors. The ability of pinyon and juniper litter to inhibit germination (Jameson, 1961, 1966) is partial explanation for the decrease in understory cover and diversity with the increasing age of a stand. The shade from the tree canopy is not usually effective in limiting understory development because of the limited canopy cover and the availability of

reflected light (Shirley, 1945). Shade from the tree canopy may be beneficial to some species by reducing evaporation rates (Jameson, 1966). This was noted in the study area for fremont goosefoot (Chenopodium fremontii) and several moss species. Competition for available moisture is thought to be more important in the distribution of understory species than any other single factor in the pinyon-juniper type.

Three recognizable associations were distinguished for the study area pinyon-juniper type. They are the pinyon pine-Utah juniper-mixed brush association, the pinyon pine-Utah juniper-big sagebrush association, and the pinyon pine-Utah juniper-woodland association.

The pinyon pine-Utah juniper-mixed brush association had the highest average elevation of the three associations [2,176 m (7,140 ft)]. It was found on cooler north- and east-facing, relatively steep (averaging 11^{o}) slopes. The total tree cover for this association was lower than the average for the pinyon-juniper type as a whole (15% versus 21%). The high ratios of pinyon cover (11%), density (115 individuals/ha) and basal area (17 m^2/ha) to juniper cover (4%), density (58 individuals/ha) and basal area (6 m^2/ha) may be indicative of the relatively high moisture availability within this association.

The shrub stratum within this association had the greatest cover (20%) and density (5,867 individuals/ha) of any of the three associations. The most abundant shrub species were those typical of the mixed brush type, Utah serviceberry (8% cover), big sagebrush (7% cover), bitterbrush (1% cover) and true mountain mahogany (1% cover). Young pinyon plants were also frequent (90% of all samples) in the shrub stratum.

The herbaceous stratum was not well developed and only supported 21 species with a total cover of 4%. Slender wheatgrass was the only species with more than 1% cover.

The pinyon pine-Utah juniper-big sagebrush association occurred at the lowest average elevation (6,310 ft) within the type. It was generally found on gentle

upland slopes and ridges and showed no preference for a particular slope aspect. The comparatively high cover (11%), density (181 individuals/ha), and basal area (21 m^2/ha) of Utah juniper over the cover (9%), density (119 individuals/ha), and basal area (4 m^2/ha) of pinyon may be indicative of the relatively dry conditions that prevail at these sites.

The shrub stratum was dominated by big sagebrush with 7% cover. The remaining 13 shrub species contributed only 2% of the total 9% shrub cover and none of these species contributed more than 1% cover. The herbaceous stratum was the best developed of the three associations with 8% total cover. The six species with the greatest cover were all grasses typical of fairly dry sites, slender wheatgrass, prairie junegrass (*Koeleria gracilis*), needle-and-thread, western wheatgrass (*Agropyron smithii*), sandberg bluegrass, and Indian ricegrass.

The pinyon pine-Utah juniper woodland association represented the most mature stage of the pinyon-juniper type.

This associations' average elevation (6,900 ft) lay near the average elevation for the pinyon-juniper type (6,940 ft). This association showed no preference for any particular slope aspect and was usually located on gentle upland slopes and ridges. The slightly higher cover and basal area of pinyon as compared to the cover and basal area of Utah juniper appeared to agree with Woodbury's (1947) suggestion that pinyon tends to replace juniper in mature stands. The high total cover and basal area of the tree stratum for this association is indicative of the relatively large size of trees. The low total cover of the shrub and herbaceous strata is indicative of the monopolization of the habitat by tree species despite the moderate tree canopy cover. No shrub species provided greater than 1% cover and only one herbaceous species (Sandberg bluegrass) exhibited more than 1% cover. Cover values may be referenced in Tables 3-7-21, 3-7-22, and 3-7-23 in the Second Annual Report (RBOSP, 1976).

5) *Sagebrush* - The sagebrush type on the study area was characterized by the constant presence, high cover, and high density of big sagebrush in the shrub stratum and by an herbaceous stratum with high species

diversity, but generally low cover. The sagebrush type occured over a wide elevational (6,420-8,580 ft) range than any other type found on the study area, and generally occurred on gentle slopes. The sagebrush type occurred on deep alluvial soils in valley bottoms (Glendive series), on mixtures of moderately deep aeolian and residual soils (Rentsac and Piceance series), and on gently sloping upland (Yamac series) and shallow residual soils of the Rentsac series, located primarily on uplands and valley side-slopes.

On the study area the sagebrush type intergraded with the pinyon-juniper type at lower elevations along drainages, and on uplands along the ridges above the major drainages. Boundaries between sagebrush and pinyon-juniper types were frequently very distinct along transitions between alluvial bottomland sagebrush stands and pinyon-juniper stands occurring on steep shale outcrops. Transitions are often very gradual between the two types in areas where soil depth does not vary sharply. Big sagebrush was a frequent component of the understory in the pinyon-juniper type, and decreased in abundance with increasing density and cover of pinyon and Utah juniper. The sagebrush type also intergraded gradually with the mixed brush type on gentle upland slopes. Cover of Utah serviceberry increased with increasing elevation, and with transitions to cooler slope aspects.

The shrub stratum in this type contributed an average cover of 30%, and average density of greater than 13,000 individuals/ha over the study area. Although 17 shrub species were encountered in this type, *Artemisia tridentata* generally provided 75% of the total cover, and 60% of the total density in the transects sampled. Frequent associates in the sagebrush type were green rabbitbrush (*Chrysothamnus viscidiflorus*) and Utah serviceberry. Phenology of common shrub species was divided between fall-blooming composite species (big sagebrush and green rabbitbrush), and spring and early summer-flowering species (Utah serivceberry and mountain snowberry).

The herbaceous stratum in this type contributed cover ranging from less than 10% during May-June to a maximum of 17% during July. The herbaceous stratum was chatacterized by a large number of species (100) which were heterogeneously

distributed, without strong dominance by any one species. This heterogeneity reflects the wide elevational range of the type, which includes a number of microclimates within its boundaries. The dominant species over the type for all sampling periods, bluegrasses, ranged in cover from 1% in May-June 1975 to nearly 2% in July. There was a high persistence of species, with approximately 70% of all species shared in common between sequential sampling periods. Flowering of herbaceous species occurred primarily in early to late spring, when highest soil moisture levels were present. Almost no species were reproductively active during September, indicating high moisture stress near the soil surface in late summer. By contrast, big sagebrush and rabbitbrush were flowering during this period.

The sagebrush type was divided into four major associations, the upland and bottomland sagebrush, rabbitbrush, and greasewood associations. The rabbitbrush and greasewood associations are discussed in separate sections. The sagebrush associations (upland and bottomland sagebursh) were distinguished from each other by their occurrence on different soil types (alluvial versus residual), and by the taller stature and greater density and cover of bottomland sagebrush stands. Upland sagebrush had a much wider elevational range, occurring from nearly level areas on lower elevations of 84 Mesa up to high elevation east slopes just below the summit of Cathedral Bluffs. Cover of the bottomland sagebrush association did not show a strong response to increase in elevation. Cover in upland sagebrush transects increased slightly with elevation, but total cover was almost always less than cover in bottomland associations, regardless of elevation. These cover differences probably reflect a more reliable moisture supply in bottomland sagebrush stands. Herbaceous cover increased with elevation in the upland sagebrush association, but remained at a low level on all bottomland associations, reflecting either substantial competition from the shrubs, or intensive grazing.

The shrub stratum of the bottomland sagebrush association contributed a total cover of 43%, and a total density of 18,880 individuals/ha. Common species were big sagebrush, rubber rabbitbrush and mountain snowberry. Five percent cover was recorded for the herbaceous stratum during July. Western wheatgrass and Great Basin wild rye (Elymus cinereus) were the dominant herbaceous species.

The shrub stratum of the upland sagebrush association contributed a total cover of 30%, and total density of 9,345 individuals/ha. Other frequent species were green rabbitbrush, Utah serviceberry, and mountain snowberry. Fifty-one herbaceous species contributed 27% total cover during July, 1975. Tailcup lupine and sandberg bluegrass were the dominant species on the transects sampled.

6) Greasewood - The greasewood association occurred as small isolated patches within the bottomland sagebrush association. It is frequently an indicator of saline-sodic soils (Rickard, 1967), and occurs on deep-well-drained soils formed in alluvial deposits which usually have dependable groundwater. It shared dominance with big sagebrush. It is unclear whether on the study area this is due to disturbance or relative soil alkalinity.

Phenological data indicate that greasewood flowers during mid-summer, forming seeds during late summer and early fall. The highest density of sagebrush seedlings in greasewood stands indicated that greasewood may be a secondary successional element in bottomland sagebrush stands on the study area.

Seasonal variation in the herbaceous stratum showed that three annuals, annual stickseed (Lappula redowskii), fremont goosefoot, and pinnate tanseymustard (Descurrainia pinnata), were the most common species contributing over 50% of a total 12% cover during May-June of 1975. Western wheatgrass was the most common perennial species. Stands sampled in Yellow Creek have been seeded with crested wheatgrass (Agropyron desertorum).

By July, the total herbaceous cover had increased from 12% cover in May-June to 29% cover. The greatest cover was again attained by annual species, summer cypress (Kochia iranica) and lambs quarter goosefoot (Chenopodium album). These species showed a tendency to be clustered together by their high sociability values. Western wheatgrass was the most common perennial species.

7) Rabbitbrush - The rabbitbrush association sampled in the study area represents a successional stage in the bottomland sagebrush

association. Most of the stands sampled in the study area are on abandoned agricultural lands or show evidence of the removal of big sagebrush by burning, defoliation or mechanical means. Burning of rabbitbrush normally kills it back to the soil surface only, and then it sprouts from the roots and increases in density by seedling establishment (Daubenmire, 1975).

In the study area the elevational, topographic, and edaphic factors were essentially the same for the rabbitbrush association as they were for the bottomland sagebrush association. It was found on floodplains and low terraces along major drainages surrounded by the sagebrush type. Rabbitbrush was always the dominant species with 90 to 91% relative cover. In the study area, rabbitbrush formed flower buds during mid-summer and flower in late summer and early fall.

The herbaceous stratum may be dominated by Great Basin wild rye (80%) relative cover), which can completely conceal the shrubs by mid-summer by attaining a greater height. Young stands of rabbitbrush were more likely to have a herbaceous understory of annuals such as Fremont goosefoot.

Herbaceous species were found flowering during May-June, and disseminating seeds by July. Some reproductive activity was still evident in September, unlike the majority of bottomland sagebrush and greasewood transects sampled, where nearly all species were vegetative, dead, or dormant in September.

8) Bald - The bald type was characterized by the absence of developed tree and shrub strata, and a diverse herbaceous cover consisting of perennial forbs and grasses. The term "bald" adequately describes the open bare slopes surrounded by communities dominated by taller shrubs or trees, and also implies a harshness which characterized those windswept areas that occur along the summit of Cathedral Bluffs, and on exposed ridges at lower elevations. The bald type ranged in elevation from 2,204-2,606 m (7,230-8,550 ft), and occurred almost exclusively (80%) on west slope aspects facing the prevailing wind. Transects were sampled primarily on the Rentsac soil series. Field observations indicate that soils were frequently extremely shallow and rocky.

Shrub species occurred sparingly on the bald type (1-5% cover), and were usually of very low stature. Utah serviceberry provided the most cover, but was generally restricted to more protected sites. Low stature shrubs characteristic of this type were green rabbitbrush and horsebrush.

The diverse (60 species) herbaceous stratum consisted of low grass and forb species that frequently formed a carpet-like mat that assists in reducing dessication by strong winds. Total cover ranged from less than 10% in May-June to greater than 20% in July. Dominance was usually shared by several species.

Species contributing greatest cover were slender wheatgrass, prairie junegrass, tufted milkvetch (*Astragalus spatulatus*), and mat penstemon (*Penstemon caespitosus*). Many of the species encountered in the bald type were also encountered in the herbaceous stratum of the sagebrush and pinyon-juniper types, indicating a compositional continuity within these communities.

During the May-June, 1975 sampling period, nearly all species were in a vegetative state, over half the species were flowering or forming seeds in July, and nearly all species declined to a vegetative state in September.

9) *Shadscale* - The shadscale type occurred over a short elevational range [1,969-3,076 m (6,460-6,810 ft)] in narrow bands on steep, generally south-facing slopes adjacent to major drainages within the study area. It occurred on rock outcrops or very shallow soils derived from sandstone cliffs or platy siltstone outcrops.

Total shrub cover was low (14 to 16%). Shadscale shared dominance with three shrubs from the sagebrush type, big sagebrush, green rabbitbrush, and rubber rabbitbrush (*C. nauseosus*), indicating its close relationship to the sagebrush type.

Herbaceous cover was extremely low in May-June, totaling less than 1%. In July, it had increased in total cover to just under 3%, with eriogonum (*Eriogonum lonchophyllum*) measuring just over 1% cover. In September, the cover values changed very little, decreasing in total cover by less than 0.5%. Indian ricegrass showed a high constancy in all sampling periods.

10) Riparian - The riparian type in the study area consisted of three different types of environments: small springs in open alluvial bottomlands that have been converted to pastureland (e.g., Stake Springs, T2S R99W S14) occupied by common pasture weeds; hillside springs and seeps along the bottom of steep draws (e.g., Cottonwood Spring, T2S R99W S19) which were not heavily grazed and contain several unusual species for the Piceance Basin; and drainageways of intermittent streams that contain species characteristic of the bottomland sagebrush association.

Tree species were not frequent in this type. Aspen appeared on one transect sampled at a high elevation. A few large individuals of narrowleaf cottonwood (*Populus angustifolia*) were observed at Cottonwood Spring.

Dominants in the shrub stratum, big sagebrush and rubber rabbitbrush were found along the drainageways of intermittent streams. In a few isolated areas (Cottonwood Spring, Duck Creek), more characteristic riparian species were found: water birch (*Betula fontinalis*), willow (*Salix exigua* and *Salix interior*), and red osier dogwood (*Swida sericea*). In wet pastures, shrubs were largely absent except for rubber rabbitbrush, which occurred around the fringes. Total shrub cover for the type ranged from a low of 2% cover on disturbed pasture sites to 25% cover for transects sampled in hillside springs and along intermittent streams.

Permanent herbaceous quadrats were located in wet pasture sites. As a result, the high total cover (50-80%) reflects the very moist growing conditions. Quackgrass (*Agropyron repens*), Kentucky bluegrass (*Poa pratensis*) and common dandelion (*Taraxacum officinale*) were common constituents of wet pastures. Several unusual herbaceous species were collected on moist sites in the vicinity of Cottonwood Springs. These included an endemic columbine (*Aquilegia barnebyi*), and alpine pyrola (*Pyrola asarifolia*), and species restricted to cool, damp sites. Fowl mannagrass (*Glyceria striata*) was found only in areas of permanent running water.

Phenology of several species occurring in pastureland areas could not be evaluated because of heavy grazing. Species in streamside habitats were frequently found to be flowering and forming seeds on the same plant, possibly indicating a longer flowering season in these areas with greater available moisture.

B. Grazing Exclosure

1. Objectives - The grazing exclosure established on Tract C-a is designed to demonstrate and monitor vegetation responses to the exclusion of particular groups of grazing or browsing herbivores. Various forage species can be expected to respond to protection according to their position in the hierarchy of consumer preferences. Thus, the most desirable components of the plant community should react most dramatically to a release from the restraints exercised upon them by certain herbivores.

2. Methods

a. Data Collection - An enclosure encompassing 1.21 ha (3 A) has been situated on Tract C-a in the southwest quarter. The exclosure contains three compartments each constructed to prevent access by particular groups of herbivores (National Academy of Sciences-National Research Council, 1962).

See pages 3-7-192 through 3-7-198 of the Second Annual Report for a complete discussion of methodology used in grazing exclosure studies.

b. Data Analysis - See pages 3-7-198 through 3-7-199 in the Second Annual Report (RBOSP, 1976) for specific grazing exclosure data analysis methods and formulae.

3. Data Summary - See pages 3-7-199 through 3-7-200 of the Second Annual Report (RBOSP, 1976) for specific results of grazing exclosure studies.

4. Discussion - The data contained in this section are baseline material intended for comparison with data from future years. Only after these comparisons are made can the objectives of this study be satisfied. It is important

to recognize that initial differences between sample grids may exercise considerable influences on the responses elicited from the various treatments. Current differences can be attributed to slight variations in slope and aspect within and between the sample plots. It should be understood that these influences will exert differential pressures on the responses of each sample site and that these responses will not necessarily be directly proportionate to the degree of protection from grazing and browsing. The response of sample sites to degrees of release from grazing pressures will be measured in future years with the aforementioned considerations in mind.

C. Range Analysis

1. Objectives - Range, browse, and soil condition and trend are the principal criteria influencing grazing management decisions on federally administered lands. This program was designed to determine the range condition (the current condition of the range in relation to the potential of which the site is capable) of all circumscribed plant communities that have been mapped for Tract C-a and adjacent areas within a radius not exceeding 5 mi of Tract C-a. A qualitative determination of the inclination of range condition toward improvement, stabilization, or deterioration, was also estimated. Concurrently, browse and soil conditions and trend were evaluated.

2. Methods

a. Data Collection - The procedures used to establish vegetation condition and trend were consistent with common range analysis practices as described in detail in United States Department of Agriculture Forest Handbook 2209.21R3 (Range Environmental Analysis Handbook, 1970).

Plant vigor and current soil erosion, factors used in the range analysis in addition to vegetation and soil trends, were visually evaluated and recorded. Vigor ratings were made only on available decreaser and increaser species and scored on a 0-10 scale.

At each browse sampling point, browse plants were given an age and form class designation. These designations, based on criteria presented by Patton and Hall (1966), were also recorded. A more complete discussion of methodology used in range analysis studies is presented on pages 3-7-206 and 3-7-207 in the Second Annual Report (RBOSP, 1976).

b. Data Analysis - A discussion of the methods used to analyze range, soil and browse condition data is presented in the Second Annual Report (RBOSP, 1976), pages 3-7-208 through 3-7-209.

3. Data Summary - The figures presented in this section are not absolute. For the ranges of these figures see the Second Annual Report (RBOSP, 1976). The study area covered approximately 35,269 acres and encompassed six major vegetation types; pinyon-juniper, sagebrush, mixed brush, upland meadow, aspen, Douglas fir, and one variant of a major vegetation type, greasewood. These were distributed as follows: pinyon-juniper -- 13,930 acres or 39.5% of the area; sagebrush -- 11,853 acres or 33.6% of the area; mixed brush -- 8,499 acres or 24.1% of the area; upland meadow -- 496 acres or 1.4% of the area; aspen -- 313 acres or 0.9% of the area; Douglas fir -- 115 acres or 0.3% of the area; and greasewood (variant of sagebrush vegetation type) -- 63 acres or 0.2% of the area. The survey area was situated so as to encompass Tract C-a and the full spectrum of elevational zones and vegetation types which surround it. See pages 3-7-211 through 3-7-242 in the Second Annual Report (RBOSP, 1976) for tabulated results of range analysis studies and for figures showing range analysis sampling sites.

a. Range Condition and Trend - The major proportion (73.1%) of the study area, 25,823 acres, was in "Fair" condition. Only 2.4% or 846 acres was classified in "Good" condition. Most of this, 631 acres, was in sagebrush communities. The remainder consisted of aspen and Douglas fir vegetation types. A total of 8,609 acres or 24.4% of the area was placed in the "Poor" condition class. Pinyon-juniper (6,939 A) and sagebrush (1,643 A) sites contributed the largest proportions to this "Poor" condition class.

No sites were in either the "Excellent" or "Very Poor" condition classes. Few sites on the study area, however, have the potential for achieving the former condition. Range condition classification is predicated on the hypothesis that vegetation is a product of environment, subject to physical, edaphic, and biotic influences and limitations. Many western rangelands have never attained climax status because of one or more of these limitations. The great time involved to arrive at climax or "Excellent" condition precludes that condition from being a practical management objective (Stoddart and Smith, 1955).

Almost one-half of the study area, 48.5% or 17,100 acres was placed in the category of upward or improving range trend. Sites totalling 2,886 acres or 8.18% of the area exhibited stability or no apparent trend. The areas assigned a downward or deteriorating trend encompassed 15,291 acres or 43.4% of the total. The greatest proportion of deteriorating rangelands (12,801 acres) were in the pinyon-juniper vegetation type.

b. Soil Condition and Trend - Soil condition and trend is related closely to the amount of ground cover including vegetation, rocks, and litter relative to the amount of bare ground.

Only 133 acres or 0.4% of the study area were found to be in the "Excellent" condition class. All of these were in the aspen vegetation type. Seven hundred and fourty-six acres of 2.1% of the area were in "Good" condition. Sites in "Good" condition were found in the sagebrush, aspen, and Douglas fir types. "Fair" soil condition was found on 2,805 acres or 7.9% of the area. Most of the soils within the study area, 86.7% or 30,573 acres, were determined to be in the "Poor" condition class. Only 2.9% of the area, 1,010 acres, was in the "Very Poor" condition. All of the sites within the upland meadow (grass bald) community were in this condition class.

Soils on 21,825 acres, or 61.9% of the study area, were in a downward trend. Almost a third (29.5%) of the area -- 10,421 acres -- was placed in a stable

or no apparent trend category. A small minority of the study area, 9.6% or 3,022 acres, was in improving or upward trend. Soils exhibiting a decline in their ability to support life (downward trend) were found primarily in the pinyon-juniper vegetation types, followed by those in the sagebrush and then the upland meadow associations.

c. Browse Condition and Trend - Browse condition studies consider only three possible condition classes - good, fair, and poor. Browse condition was determined to be almost entirely (98.4%) within the "Good" condition class. The area encompassed by this category comprised 34,219 acres. A collective area of sites totalling 482 acres, 1.4% of the area, was placed in the "Fair" condition class. Seventy-three acres, 0.20% of the area, were judged to be in "Poor" condition.

Even though most of the browse was in good condition, the largest portion, 59.7% or 20,756 acres, exhibited a downward trend. An area about one-half that size, 10,435 acres or 30.0% of the acreage, showed no apparent trend.

4. Discussion - Range condition classes can be described conceptually as stages of plant community succession or retrogression, resulting from physical, edaphic, and biotic interactions. The latter category includes the grazing impacts of domestic livestock, wild horses, big game, and smaller herbivores and is the most amenable to manipulation by man.

Range condition and trend studies do not conclusively indicate an overall, intensive short-term overuse by ungulates in the study area. However, approximately, 88 wild horses (personal communication, 1976, Bill Lawhorn, Meeker BLM) in addition to mule deer, elk, and domestic livestock, have been observed on the Box Elder Allotment in the study area. This concentration of ungulates using the Box Elder Allotment could cause overgrazing on this portion of the range. Three-fourths of the area was found to be in "Fair" condition, almost one-fourth in "Poor" condition, and a small percentage in "Good" condition. A slightly greater proportion (48.5%) of the area exhibited an upward trend or improving condition compared to that showing a downward trend (43.4%). The remaining sites showed no apparent trend. These comparisons indicate a state of relative equilibrium and no conclusive tendencies.

Soils, however, were found to be in a relatively depleted condition, with 86.7% of the area soils in "Poor" condition. Moreover, 61.9% of the area's soil showed a decline in its ability to support life (downward trend). Only 8.6% of the study area's soil exhibited an upward trend while the remainder showed no apparent trend. The studies indicate that although rangeland vegetation may have generally stabilized, soil conditions exhibit a downward trend.

An analytical evaluation of the data assembled during the range studies suggests that one of two processes may be occurring on the study area. Both processes are propounded here as hypotheses for the consideration of the reviewer, and arguments in support of each are explored and explicated. Long-term studies would be necessary to establish the absolute validity of either theory.

One possibility is that a differential exists between the range and soil recovery curves, or a "time lag" delays the response of soil conditions. If a recovery has occurred on most ranges within the study area, condition has stabilized; i.e., consumption by herbivores is not adversely affecting community composition, plant density, or plant vigor. Conversely, soil conditions are generally lower and continuing to decline. It should perhaps be explained that changes in condition and trend are not immediate responses to release from grazing or other disturbance. There is a "momentum effect"--that is, alleviation of the stress factor may require a number of years for a "turnaround". If this is the case, there has not yet been a distinct tendency for stabilization or improvement of soil conditions. There are a multitude of factors or interactions of factors which may be affecting the recovery differential. A most logical explanation might simply be that soil responses to improved conditions require a longer time to manifest themselves than do vegetation responses. A climatic shift or a change in precipitation patterns or intensities could influence soil conditions and trends but meteorological records do not indicate that such is the case (refer to Section 3, Chapter 6 for more detailed information). Even though many of the forage plants present are desirable, their low density and inability to form a closed canopy expose large proportions of bare soils to the elements. Features inherent

in the soils themselves, such as their high erodability, may make soil movement (hence the condition) a natural phenomon of the regional geology.

There is evidence to support this theory. In 1969, the Cathedral Bluffs Grazing Unit was divided into individual grazing allotments. Management plans to ensure more efficient utilization of forage and a more balanced allocation of that resource were implemented by the BLM on the Square S and Reagle Allotments four years ago (personal communication, November, 1975, Stan Colby, Bill, Lawhorn, Meeker, BLM office). Ranchers interviewed in the area believe that local ranges have been improving gradually for the past several years and looked better this past season than at any time in recent years (personal communications, July, 1975). Mule deer, which utilize the area for winter and transitional ranges, have decreased drastically since the 1950's (personal communication, 1975, Colorado Division of Wildlife).

A second hypothesis would perceive the range condition and trend studies inconclusive. Range condition is only one of several indicators of the health and well-being of a grazing ecosystem. Although the applied methodology revealed local ranges to be in generally moderate condition, these ratings were heavily influenced by the relatively high numbers of desirable forage species. The other factors considered in determining condition (cover and vigor) were generally low. Widespread retrogradation of soils in the study area and low forage production (see Production-Utilization Section) are other indicators which may reflect a declining capacity of these ranges to support existing ungulate populations. The increase of wild ungulates on certain portions of the range with no recent concerted effort to control ungulates numbers may be an important factor in that decline.

In general, poor condition is most widespread on the Box Elder Allotment. The licensed numbers of livestock using the allotment (see Domestic Livestock Section) in the past five years (1,124-1,344 AUM's) is well within the carrying capacity (1,517 AUM's). However, the combined requirements of domestic livestock, wild horses, mule deer and elk exceed the carrying capacity. The BLM is currently preparing an Allotment Management Plan for the Box Elder Allotment which will help to alleviate this problem by taking into account the pressures exerted on the range by ungulates other than domestic livestock.

Field studies to determine carrying capacity for cattle and horses were conducted on portions of the study area in 1973 by the BLM, but condition and trend determinations were not made at that time.

Range conditions were better on north-facing slopes which retained soil moisture longer into the growing season than on south-facing slopes.

Browse conditions on the study area were overwhelmingly in the "Good" condition class. The largest portion, however, was seen to exhibit a downward trend, or a deterioration in condition. Mule deer use the area primarily as transitional ranges except in mild winters (see Aerial Big Game Censuses Section), a fact which is reflected in the favorable condition which prevails. A preponderance of large overage shrubs containing decadent or dead material is thought to account for the downward trend.

D. Range Production-Utilization

1. Objectives - Forage production and utilization studies were undertaken to measure the actual forage being produced annually per unit area within each major association. The amount of forage taken by large herbivores at a given point in time is also measured. These studies will reveal the relative preferences of herbivores for particular plant associations.

2. Methods

a. Data Collection - Grass and forb production utilization studies were conducted within four principal plant associations: pinyon-juniper, sagebrush, mixed brush and grass balds. After completion of the growing season in late August or early September, forage utilization was measured by comparing clippings from plots which were protected from grazing with clippings from plots which were unprotected. Ocular estimates of forage production were made concurrently to supplement this method. All clipped samples were returned to the ECI laboratory, oven-dried at 70^{o}C for at least 24 hours in a Thelco oven and weighed again to provide dry weight estimates.

b. Data Analysis - A discussion of the methods and formulae used to analyze range production-utilization data is presented on page 3-7-247 of the Second Annual Report (RBOSP, 1976).

3. Data Summary - Figures presented are not absolute. See the Second Annual Report for ranges of these figures. Production varied widely over the study area from a mean of 92.86 pounds/acre (104.93 kilograms/hectare) on pinyon-juniper sites to 240.00 pounds/acre (271.20 kilograms/hectare) on mixed brush sites. Sites located in the sagebrush vegetation type produced an average 185.50 pounds/acre (209.62 kilograms/hectare) and upland meadow (grass bald) sites produced 172.00 pounds/acre (195.49 kilograms/hecatre).

Utilization studies were undertaken concurrently with productivity studies. Such studies would normally be conducted at the conclusion of the grazing season, but there is grazing by ungulates (cattle, mule deer, elk, wild horses) within the study area year-round. The end of the growing season, approximately the beginning of September, was selected as the sampling period since the time was optimum for productivity clipping. Because of aforementioned conditions, there is no optimum time for obtaining utilization measurements. Those that follow should be interpreted as relative indices of herbivore utilization on the various vegetation types through completion of the growing season, but not as total annual utilization. Utilization totalled only 7% on sagebrush sites but was up to 44% on mixed brush types at the time of sampling. Forage utilization on upland meadow (grass bald) sites was 43% and 24% on pinyon-juniper sites. See page 3-7-253 in the Second Annual Report (RBOSP, 1976) for tabulated results of range production-utilization studies.

4. Discussion - Utilization ranged from 7% on sagebrush sites to 44% on mixed brush sites. Upland meadow (grass bald) sites had 54% of total forage production utilized and pinyon-juniper sites received 24% utilization. These figures represent, in direct proportion, the relative preferences of herbivores for these plant associations.

Forage production on all four plant associations was generally low in 1975. Precipitation was subnormal this past year based upon information obtained from compilation of weather records from Rifle, Meeker, and Rangely, Colorado, a factor which may have influenced productivity. Pinyon-juniper sites were the lowest producing ranges while the mixed brush vegetation type produced the highest amount of forage.

Forage productivity is influenced by a myriad of abiotic and biotic factors as well as by man. The mixed brush vegetation, for example, exhibited the greatest productivity, probably because of the deeper soils (with the exception of bottomland sage stands on alluvial deposits) and the most favorable moisture conditions that prevail there. The pinyon-juniper sites were the least productive probably due to the shallow soils, lesser annual precipitation, and competition for soil moisture between forage and canopy species. The fact that wild horses and mule deer concentrate in these sites during winter months to seek respite from chilling winds and temperatures may also contribute to the low productivity observed on pinyon-juniper sites. The sagebrush vegetation type showed the most variability in production probably because no distinction was made between upland and bottomland sites in this analysis. Bottomland sagebrush sites on deep alluvial deposits where basin wildrye (Elymus cinereus) was dominant were highly productive, whereas some upland sites were almost devoid of a grass-forb understory. These differences were attributed to variations in soil depth, and soil moisture competition. The upland meadow (grass bald) sites showed generally low productivity possibly because these areas are generally swept clean of snow by high velocity winds and do not receive the full benefit of precipitation occurring as snow. In addition, winter aerial surveys have indicated that these areas are utilized heavily during winter by wild horses.

In late spring, 1976, browse production-utilization investigations to determine annual browse production as indicated by mean twig length will be conducted. The amounts of this production actually taken by wintering ungulates will also be determined.

7.2 FAUNA

A. Small Mammals

1. Objectives - The small mammal census program is designed to identify the species of small mammals that occur within Tract C-a and the contiguous area and to determine densities of the most abundant species in dominant habitats. Seasonal periodicity of activity, food habits and reproductive effort of important species are to be described. Small mammal habitat affinity will be determined and species diversity values will be calculated for the various habitats.

2. Methods

a. Data Collection

1) Live Trapping - A live trapping program, consisting of trapping periods during the 2-year baseline inventory, was initiated during October, 1974. To coincide with periods of increased small mammal activity and to provide adequate data on reproduction and other population parameters, sampling was conducted during October, 1974, May, July, and September, 1975 and will occur during May, July, and September, 1976. Trapping periods during December, 1974 and 1975 will provide information on small mammal winter activity patterns.

2) Collection of Animals for Laboratory Analysis - A removal trapping program designed to collect small mammals of the three most common species (deer mouse, least chipmunk and long-tailed vole) for laboratory analysis of reproductive effort or stomach contents during each of the small mammal live trapping periods.

3) Laboratory Analysis of Reproductive Effort - The number and condition of placental scars, pigmented areas of the uterus occurring at sites of previous placental attachments, has been used to determine litter size in small mammals (Davis and Emlen, 1948; Corthum, 1967). Since placental scars become increasingly lighter with age (Corthum, 1967), the degree of scar pig-

mentation can be used to indicate the approximate date of birth. Thus, by examining the reproductive tract of adult females of selected species at times during the breeding season, information on litter size, number of litters per season, and date of birth can be provided.

4) Laboratory Analysis of Stomach Contents - Basic dietary preferences of small mammal species are becoming well-studied by mammalogists and a solid literature base is developing which can be employed to support interpretation of trophic relationships of mammals within various plant communities. The International Biological Program's Grassland Biome work has provided recent data on small mammal diets through its Diet Laboratory in Fort Collins (e.g., Grant, 1972; Hansen and Moir, 1971; Flinders and Hansen, 1972). These data will be utilized wherever feasible to support interpretation of dietary habits and trophic level position of the small mammal species found on or near Tract C-a.

5) Collection of Voucher Specimens - To confirm field identification and to provide evidence of species encountered during the baseline inventory, up to five voucher specimens of each small mammal species captured are being prepared. Identifications are checked by Dr. Robert B. Finley, a mammalogist with the National Fish and Wildlife Laboratory, familiar with the mammals of western Colorado.

6) Pitfall Trapping - Pitfall traps for "trap-shy" animals and for small mammals not attracted to peanut butter bait are established in each of the vegetation communities sampled by the live trapping grids and in the riparian habitat beside the pond in Stake Springs Draw. Species, sex, age, habitat type and pitfall location are recorded for each captured animal. Up to five individuals of each species found dead in the traps are being prepared as voucher specimens, while live animals are released.

7) Night Spotlight Census - A night spotlight census route has been established to record activity, distribution, and abundance of nocturnally active mammals, particularly lagomorphs and other medium-sized mammals. This census is being conducted on two clear nights during February, June, and October of each year along a 48.4 km (30 mi) route which traverses all major vegetation associations within and adjacent to Tract C-a.

8) Bat Investigations - During the summer months of June and August, 1975 and 1976, two different techniques are employed to determine the distribution and relative abundance of bat species within and adjacent to Tract C-a.

Hall and Kelson (1959) is the authority used for small mammal nomenclature. See pages 3-7-258 through 3-7-265 in the Second Annual Report (RBOSP, 1976) for complete methodology used in small mammal sampling.

b. Data Analysis - For specific methods and formulae used in small mammal data analysis refer to pages 3-7-266 through 3-7-272 in the Second Annual Report (RBOSP, 1976).

3. Data Summary - Figures presented in this section are not absolute. See the Second Annual Report (RBOSP, 1976) for ranges of these figures.

b. Live and Removal Trapping - Fourteen different vegetation types were sampled by small mammal live trapping grids during October and December 1974 and during May, July and September-October, 1975 (Table 3-7-1). Removal trap lines were established in vegetation types sampled by grids A-E and G during December, 1974 and May, July, and October, 1975 to collect adult deer mice (*Peromyscus maniculatus*), least chipmunks (Eutamias minimus), and long-tailed voles (Microtus longicaudus) for analyses of reproductive efforts and stomach contents. Approximately 2,700 small mammals representing 13 different trappable species have been captured to date.

Data collection from small mammals captured during trapping operations are summarized and presented below. Three major topics are considered. First, the relative importance of each habitat type to the diversity and abundance of small mammal populations is discussed. Secondly, the ecological distribution, abundance, and variation of population parameters among habitats is described for each small mammal species captured. Finally, seasonal variations in small mammal population levels are discussed.

Table 3-7-1

SITE DESCRIPTIONS FOR SMALL MAMMAL, AVIFAUNA AND INVERTEBRATE SAMPLING LOCATIONS FOR RBOSP

LOCATION DESIGNATION				
Small Mammals	Avifauna	Invertebrates	Vegetation Type	Aspect/Elevation
1	1		Bottomland meadow	Flat/6300'
2	2		Sagebrush	Flat/6500'
3	3		Rabbitbrush	Flat/6800'
4	4		Pinyon-juniper/mixed brush	North/7400'
5	5	5	Mixed brush	North/7200'
6	6		Pinyon-juniper/sagebrush	Flat/7400'
7	7		Upland meadow *	Flat/8500'
A	8	1	Greasewood/sagebrush	Flat/6400'
B	9	2	Pinyon-juniper	South/7000'
C	10	3	Pinyon-juniper	North/6900'
D	11	4	Sagebrush	North/7100'
E	12		Mixed brush	South/8300'
F	13		Douglas fir	North/8200'
G	14		Aspen	North/8100'
	15		Riparian	Flat/6700'

* The designation "bald" was used for this type during vegetation sampling.

1) Small Mammal Habitats - Determination of the relative importance of different habitats to small mammal populations will focus on a comparison of three estimated parameters: species diversity, species composition, and abundance.

Shannon-Weiner diversity indices are provided for each grid (habitat type) during each sampling period (see Tables 3-7-65 to 3-7-70 in the Second Annual Report, RBOSP, 1976). Species diversity is a measurable characteristic which relates to the organization and functioning of the ecosystem. It incorporates both the number of species and the number of each species present in a sample taken from a community.

A summary of trapping results, expressed as individuals of all species captured per 100 trap nights, is presented for all grids during each sampling period in Table 3-7-2 and for each species on all grids during sampling periods 1, 3, 4 and 5 in Table 3-7-3. Expressing abundance as captures per 100 trap nights where one trap night is defined as a trap baited and set for approximately 24 hours permits direct comparison of results on each grid type and between sampling periods.

Macrohabitat affinities as determined by Chi-square values are presented for each species in Table 3-7-4. A total Chi-square value greater than 22.36 represents a statistically significant difference between the observed and expected (based on a random distribution of species among habitat types) number of captures. Habitat affinities are indicated by the largest positive values of a species individual Chi-square value series.

Most small mammals ultimately depend upon the vegetation for their cover, source of food and frequently their only supply of water. The amount of vegetation cover within a habitat type therefore is probably a major determining factor in the distribution and abundance of many small mammal species. To help identify causal relationships between vegetation and small mammal population parameters, percent cover of all vegetation within the tree, shrub, and herbaceous strata at each small mammal grid are presented in Table 3-7-5. Percent cover was determined from data collected on permanent vegetation phytosociological transects established on or near the appropriate small mammal grid.

Table 3-7-2

SMALL MAMMAL TRAPPING SUMMARY FOR ALL GRIDS DURING EACH SAMPLING PERIOD

		Individuals captured of all species per 100 trap nights						
Grid	Vegetation Type	Oct. 1974	Dec. 1974	May 1975	July 1975	Oct. 1975	Average	% Relative Abundance
1	Bottomland Meadow	10.91	14.55	6.67	5.05	3.64	8.43	4.6
2	Sagebrush	10.91	4.85	13.33	20.61	17.58	13.45	7.4
3	Rabbitbrush	23.64	15.15	35.76	12.73	23.03	22.05	12.2
4	Pinyon-juniper/mixed brush	24.24	2.42	22.42	13.33	12.73	15.03	8.3
5	Mixed Brush	20.61	1.21	23.03	8.48	33.33	17.33	9.6
6	Pinyon-juniper/sagebrush	18.18	6.06	21.21	15.15	13.94	14.91	8.2
7	Upland Meadow	5.45	0.00	9.09	8.48	9.70	6.55	3.6
A	Greasewood/Sagebrush	22.26	12.73	12.33	12.63	26 47	18.09	10.0
B	Pinyon-juniper (south slope)	16.54	9.09	11.14	16.09	14.44	14.94	8.2
C	Pinyon-juniper (north slope)	15.04	1.21	9.02	14.59	11.23	11.82	6.5
D	Sagebrush	15.34	1.21	9.77	7.97	6.47	9.38	5.2
E	Mixed Brush	8.57	0.00	13.08	11.13	17.44	11.82	6.5
F	Douglas Fir	8.98	7.88	8.52	7.21	8.85	8.30	4.6
G	Aspen	*	*	10.49	6.56	10.49	9.18	5.1
	Average	15.39	5.87	12.71**	11.37**	14.52**	13.07	
	% Relative Abundance	25.7	9.8	21.2	19.0	24.3		

* Grid not sampled

** For comparative purposes, Aspen data are not included in averages.

Table 3-7-3
SMALL MAMMAL TRAPPING SUMMARY BY SPECIES FOR ALL GRIDS DURING SAMPLING PERIODS 1, 3, 4 and 5*

		Number of Individuals Captured of Each Species per 100 Trap Nights												
Grid	Vegetation Type	SOME[1]	SPLA[2]	SPTR[3]	PEAP[4]	EUMI[5]	EUQU[6]	PEMA[7]	PETR[8]	NECI[9]	CLGA[10]	MIMO[11]	MILO[12]	LACU[13]
1	Bottomland Meadow	0.00	0.00	0.00	0.00	0.34	0.00	5.56	0.00	0.00	0.00	0.51	0.00	0.34
2	Sagebrush	0.00	0.00	1.82	0.15	9.70	0.00	3.94	0.00	0.00	0.00	0.00	0.00	0.00
3	Rabbitbrush	0.00	0.91	0.00	0.00	8.94	0.00	13.64	0.00	0.00	0.00	0.00	0.30	0.00
4	Pinyon-juniper/ Mixed Brush	0.00	0.91	0.00	0.15	7.58	1.67	7.88	0.00	0.00	0.00	0.00	0.00	0.00
5	Mixed Brush	0.00	0.00	0.00	0.00	13.18	0.00	8.18	0.00	0.00	0.00	0.00	0.00	0.00
6	Pinyon-juniper/ Sagebrush	0.00	0.91	0.00	0.45	4.70	0.00	11.06	0.00	0.00	0.00	0.00	0.00	0.00
7	Upland Meadow	0.00	0.00	0.00	0.00	1.06	0.00	7.12	0.00	0.00	0.00	0.00	0.00	0.00
A	Greasewood/Sagebrush	0.00	0.68	0.00	0.08	8.53	0.00	8.16	0.00	0.00	0.00	0.00	0.98	0.00
B	Pinyon-juniper (South Slope)	0.00	1.20	0.00	0.19	6.39	1.43	4.59	0.64	0.83	0.00	0.04	0.00	0.00
C	Pinyon-juniper (North Slope)	0.00	1.58	0.00	0.00	4.17	1.39	4.70	0.38	0.23	0.00	0.04	0.00	0.00
D	Sagebrush	0.04	0.90	0.00	0.00	4.02	0.00	4.51	0.00	0.11	0.00	0.00	0.00	0.30
E	Mixed Brush	0.00	0.53	0.00	0.00	5.64	0.00	5.68	0.00	0.00	0.08	0.00	0.19	0.45
F	Douglas Fir	0.00	0.00	0.00	0.00	2.41	0.00	1.38	0.00	0.00	4.48	0.00	0.09	0.00
G	Aspen	0.00	0.00	0.00	0.00	2.51	0.00	1.42	0.00	0.00	4.92	0.00	0.33	0.00
	Average	0.01	0.74	0.06	0.06	5.60	0.43	5.72	0.14	0.16	0.50	0.03	0.19	0.11
	% Relative Abundance	0.04	5.41	0.44	0.44	40.80	3.14	41.65	0.99	1.13	3.62	0.18	1.35	0.80

*Winter sampling period deleted from analysis due to the inactivity of most small mammal species during this time.

[1]SOME = *Sorex merriami*
[2]SPLA = *Spermophilus lateralis*
[3]SPTR = *Spermophilus tridecemlineatus*
[4]PEAP = *Perognathus apache*
[5]EUMI = *Eutamias minimus*
[6]EUQU = *Eutamias quadrivittatus*
[7]PEMA = *Peromyscus maniculatus*
[8]PETR = *Peromyscus truei*
[9]NECI = *Neotoma cinerea*
[10]CLGA = *Clethrionomys gapperi*
[11]MIMO = *Microtus montanus*
[12]MILO = *Microtus longicauus*
[13]LACU = *Lagurus curtatus*

Table 3-7-4

DETERMINATION OF MACROHABITAT PREFERENCE BY CHI-SQUARE VALUES* FOR ALL SPECIES CAPTURED ON EACH GRID DURING SAMPLING PERIODS 1, 3, 4 and 5**

		Species										
Grid	Vegetation Type	SPLA[1]	SPTR[2]	PEAP[3]	EUMI[4]	EUQU[5]	PEMA[6]	PETR[7]	NECI[8]	CLGA[9]	MILO[10]	LACU[11]
1	Bottomland Meadow	4.41-	0.36-	0.36-	29.38-	2.56-	0.03-	0.80-	0.92-	2.95-	1.10-	2.76+
2	Sagebrush	4.90-	338.74+	0.91+	19.78+	2.85-	3.64-	0.89-	1.03-	3.28-	1.23-	0.73-
3	Rabbitbrush	0.25+	0.40-	0.40-	13.14+	2.85-	72.46+	0.89-	1.03-	3.28-	0.49+	0.73-
4	Pinyon-juniper/Mixed Brush	0.25+	0.40-	0.91-	4.60_	23.33+	5.41+	0.89-	1.03-	3.28-	1.23-	0.73-
5	Mixed Brush	4.90-	0.40-	0.40-	67.75+	2.85-	7.03+	0.89-	1.03-	3.28-	1.23-	0.73-
6	Pinyon-juniper/Sagebrush	0.25+	0.40-	17.04+	0.96-	2.85-	33.00+	0.89-	1.03-	3.28-	1.23-	0.73-
7	Upland Meadow	4.90-	0.40-	0.40-	24.28-	2.85-	2.38+	0.89-	1.03-	3.28-	1.23-	0.73-
A	Greasewood/Sagebrush	0.16-	1.60-	0.10+	40.89+	11.48-	27.77+	3.60-	4.14-	13.21-	89.82+	2.94-
B	Pinyon-juniper (South Slope)	7.59+	1.60-	7.21+	2.97+	61.28+	5.93-	49.80+	77.11+	13.21-	4.94-	2.94-
C	Pinyon-juniper (North Slope)	25.05+	1.60-	1.60-	9.67-	56.74+	4.80-	11.35+	0.84+	13.21-	4.94-	2.94-
D	Sagebrush	0.91+	1.60-	1.60-	11.82-	11.48-	6.75-	3.60-	0.31-	13.21-	4.94-	8.73+
E	Mixed Brush	1.68-	1.60-	1.60-	0.01+	11.48-	0.01-	3.60-	4.14-	9.52-	0.00+	27.98+
F	Douglas fir	8.61-	0.70-	0.70-	21.03-	5.01-	38.16-	1.57-	1.80-	371.01+	0.62-	1.28-
G	Aspen	6.80-	0.55-	0.55-	15.56-	3.95-	29.53-	1.24-	1.42-	360.05+	1.00+	1.00-
	TOTAL	70.65	350.35	33.79	261.86	201.55	236.78	80.94	96.85	816.05	113.97	54.93

*A total chi-square value greater than 22.36 indicates a significant difference between expected and observed number of captures at the 95% confidence level. A "+" following a value signifies that the observed number of captures exceeded the expected number while a "-" implies the opposite.

**Winter sampling period deleted from analysis due to inactivity of most small mammal species during this time.

[1] SPLA = *Spermophilus lateralis*
[2] SPTR = *Spermophilus tridecemlineatus*
[3] PEAP = *Perognathus apache*
[4] EUMI = *Eutamias minimus*
[5] EUQU = *Eutamias quadrivittatus*
[6] PEMA = *Peromyscus maniculatus*
[7] PETR = *Peromyscus truei*
[8] NECI = *Neotoma cinerea*
[9] CLGA = *Clethrionomys gapperi*
[10] MILO = *Microtus longicaudus*
[11] LACU = *Lagurus curtatus*

Table 3-7-5

PERCENT COVER OF TREE, SHRUB AND HERBACEOUS VEGETATION ON OR NEAR EACH SMALL MAMMAL LIVE TRAPPING GRID AS DETERMINED FROM DATA COLLECTED ON PERMANENT PHYTOSOCIOLOGICAL TRANSECTS FOR RBOSP

Grid	Vegetation Type	% Cover-all vegetation species			
		Tree	Shrub	Herbaceous*	Total
1	Bottomland meadow**	--	0.3	67.9	65.2
2	Sagebrush**	--	21.4	7.3	28.8
3	Rabbitbrush***	--	35.5	23.0	58.5
4	Pinyon-juniper/mixed brush**	1.8	24.3	10.5	36.5
5	Mixed brush**	--	51.3	8.5	59.8
6	Pinyon-juniper/sagebrush**	--	25.8	25.9	51.6
7	Upland meadow**	--	--	20.9	20.9
A	Greasewood-sagebrush***	--	39.9	9.4	49.3
B	Pinyon-juniper (south slope)***	13.1	1.4	3.6	18.0
C	Pinyon-juniper (north slope)**	28.5	1.0	1.8	31.3
D	Sagebrush***	--	33.0	13.4	46.4
E	Mixed brush**	--	74.4	5.8	80.2
F	Douglas fir***	30.5	57.0	20.7	108.1
G	Aspen***	34.9	59.4	26.2	120.6

* Average of 3 sampling periods (May, July, and September, 1975).

** Vegetation transect is within a comparable vegetation type near the small mammal grid.

*** All or a portion of the vegetation transect is within the small mammal grid.

a) Bottomland Meadow (Grid 1) - Species diversity on grid 1 was comparatively low (0.000-0.908) during most sampling periods with no more than three species represented in any one sample. The deer mouse was the most frequently trapped small mammal on the grid (5.56 individuals/100 trap nights). The least chipmunk, montane vole, and the sagebrush vole (*Lagurus curtatus*) were also captured.

Percent relative abundance of trappable small mammals, based on the average trapping success per unit effort (i.e., 100 trap nights) over all sampling periods, was the third lowest (4.7%) among grids. This was probably due in large part to the total absence of tree cover, and very little shrub cover (0.3%) on the grid although herbaceous cover (67.9%) was the highest on all grids. As the results from other grids will emphasize, the amount of tree and shrub cover, particularly shrub cover, is an important factor which influences total small mammal abundance. A dense shrub cover definitely affords a great deal of protection, many potential nesting sites and a source of food.

b) Sagebrush (Grid 2) - Species diversity was on the average higher on this grid located on 84 Mesa (0.000-1.047) than that of bottomland meadow with as many as four species captured in one sample. The least chipmunk (9.70 individuals/100 trap nights) and the deer mouse (3.94 individuals/100 trap nights) were captured more frequently than other species and the former species exhibited an affinity for this sagebrush type. The Apache pocket mouse (*Perognathus apache*), and the thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*) were also represented in samples. The latter species exhibited a very definite affinity for this habitat type.

Although herbaceous vegetation cover was relatively low (7.3%), shrub cover (21.4%) was much higher than that for bottomland meadow. Accordingly, total percent relative abundance of animals was higher (7.4%).

c) Rabbitbrush (Grid 3) - Species diversity was very low on this grid (0.440-0.894) as most of the individuals captured were either deer mice or least chipmunks. Both species exhibited an affinity for this type

The golden-mantled ground squirrel (Spermophilus lateralis) and the long-tailed vole were also captured on the grid but were represented infrequently in samples.

Total percent relative abundance (12.17%) was the highest of any grid sampled. The high shrub (35.53%) and herbaceous (22.95%) cover were probably major contributing factors to the high capture success in this habitat type. In fact, only two other grids, grid A (greasewood/sagebrush) and grid 5 (mixed brush), both in comparable elevational zones and with a higher shrub cover and similar relative abundances, exhibited a much lower herbaceous cover, 8.52% and 9.43%, respectively.

d) Pinyon-Juniper (Mixed Brush) - The ecotonal (edge habitat) characteristics and the presence of trees are probably two important factors which resulted in a moderately high average species diversity value for this grid (0.000-1.038).

The Colorado chipmunk (Eutamias quadrivittatus), whose distribution is limited to the pinyon-juniper type within the study area was caught here. Although its relative abundance was low (1.67 individuals/100 trap nights) compared to the least chipmunk (7.58 individuals/100 trap nights) and the deer mouse (7.88 individuals/100 trap nights), the Colorado chipmunk revealed an affinity for this habitat type as did the latter two species. The golden-mantled ground squirrel and the Apache pocket mouse were occasionally captured.

The total percent relative abundance (8.3%) was the fourth highest of all grids. The moderately high shrub cover (24.3%), herbaceous cover (10.5%) and the presence of a tree stratum probably accounted for the high relative abundance.

e) Mixed Brush (Grid 5) - Species diversity was relatively low on this grid during all sampling periods (0.642-0.693) as only two species were ever captured. Both the deer mouse and the least chipmunk were trapped frequently in traps (8.18 and 13.18 individuals/100 trap nights, respectively) and both exhibited a definite affinity for the habitat type.

This grid exhibited the highest shrub cover (51.3%) of all grids established at lower elevations. Accordingly, total percent relative abundance (9.6%) was the third highest of all grids. It appears from the comparison of trapping results from homogeneous mixed brush and sagebrush types (grids 5, 2 and D) at the lower elevation that mixed brush can support more small mammals than sagebrush. Thus, in some instances, vegetation species composition may be as important to small mammal diversity and abundance as vegetation cover.

f) Pinyon-Juniper/Sagebrush (Grid 6) - Although this grid is similar to grid 4 (pinyon-juniper/mixed brush) in that it is a pinyon-juniper/shrub ecotone, species diversity was on the average lower (0.000-1.133). The largest contributing factor to the decreased diversity was the predominance of deer mice (11.06 individuals/100 trap nights) and the total absence of the Colorado chipmunk. The deer mouse as well as the Apache pocket mouse showed an affinity for this habitat type. The golden-mantled ground squirrel was captured occasionally on this grid.

Although both shrub cover (25.3%) and herbaceous cover (25.9%) were higher on this grid than on grid 4, total relative abundance was lower (8.2%).

g) Upland Meadow (Grid 7) - Species diversity here was, on the average, the lowest of all small grids (0.000-0.520). Only two species, the least chipmunk and the deer mouse, were represented in samples (1.06 and 7.12 individuals/100 trap nights, respectively) and neither exhibited a preference for the type.

Total percent relative abundance (3.6%) was the lowest of all grids. The absence of trees and shrubs and the harsh environmental conditions characteristic of the higher elevations were undoubtedly the major contributing factors in the poor trapping success shown by this grid.

h) Greasewood/Sagebrush (Grid A) - This grid exhibited the lowest average species diversity of the larger grids established in habitats below 7,500 ft elevation (0.773-1.040). Although five species were trapped, most individuals captured were either deer mice (8.16 indivduals/100 trap nights)

or least chipmunks (8.53 individuals/100 trap nights). Both species exhibited a preference for this habitat type as did the long-tailed vole (Microtus longicaudus). The golden-mantled ground squirrel and the Apache pocket mouse were captured infrequently.

Total percent relative abundance (10.0%) was the highest of the larger grids and second highest of all grids. Again, high shrub cover (39.9%) appears to be a major contributing factor even though herbaceous cover (9.4%) was low.

i) Pinyon-Juniper/South Slope (Grid B) - This grid exhibited the highest species diversity of any of the large (7.29 ha) grids (0.393-1.634). A total of eight species was trapped on this grid. Five of these species, the golden-mantled ground squirrel, Apache pocket mouse, bushy-tailed wood rat (Neotoma cinerea), Colorado chipmunk and pinyon mouse (Peromyscus truei) exhibited an affinity for the habitat type. The latter two species were limited to pinyon-juniper woodlands within the study area. The least chipmunk, montane vole and the deer mouse were also captured.

Although shrub cover (1.4%) and herbaceous cover (3.6%) were low, total percent relative abundance (8.2%) was moderately high on this grid. The presence of trees evidently was important to small mammal abundance here.

j) Pinyon-Juniper/North Slope (Grid C) - Again, largely due to the presence of the tree stratum, average species diversity was high on this grid (0.693-1.477). Except for the absence of the Apache pocket mouse, the same species were captured on this grid as on grid B. However, only three species, the golden-mantled ground squirrel, Colorado chipmunk and the pinyon mouse showed a definite affinity for this habitat type.

Tree cover (28.5%) was higher on this grid than on grid B though total small mammal percent relative abundance (6.5%) was lower. This may be attributed in part to the lower shrub (1.0%) and herbaceous (1.8%) cover.

k) Sagebrush (Grid D) - Average species diversity on this grid was comparable to that of grid A (greasewood/sagebrush) (0.000-1.165). Six species were represented in samples with the deer mouse (4.51 individuals/100 trap nights) and least chipmunk (4.02 individuals/100 trap nights) being captured more frequently.

The sagebrush vole revealed an affinity for this type. The golden-mantled ground squirrel and the bush-tailed woodrat were also captured.

Total relative abundance (5.2%) was the lowest of the large grids. The high shrub cover (33.1%) and the moderately high herbaceous cover (13.4%) does not support this trend. However, the absence of trees and the fact that homogeneous sagebrush types (excluding sagebrush stands in the bottomland drainages) tended to support fewer small mammals than mixed brush types may partially explain the lower relative abundance on this grid.

l) Mixed Brush (Grid E) - Average diversity on this grid was comparable to the other treeless large grids (0.000-1.137), although this elevation is over 1,000 ft higher. Six species were captured with the deer mouse (5.68 individuals/100 trap nights) and the least chipmunk (5.64 individuals/100 trap nights) again most abundant. However, the only species that showed an affinity for this mixed brush type was the sagebrush vole. The red-backed vole (Clethrionomys gapperi) was represented by very few captures. The golden-mantled ground squirrel and the long-tailed vole were also captured.

Shrub density (74.4%) was the highest of any grid and thus total percent relative abundance (6.5%) was higher than grid D (sagebrush) (5.2%) even though the elevation was higher and the environmental conditions probably harsher.

m) Douglas-Fir (Grid F) - Average species diversity was low on this grid (0.271-1.147) as most of the captures were of one species, the red-backed vole, which revealed a definite affinity for the Douglas fir vegetation type. The long-tailed vole, deer mouse and the least chipmunk were occasionally captured.

Even though tree (30.5%), shrub (57.0%), and herbaceous (20.7%) cover were very high, total percent relative abundance (4.6%) was the second lowest of any grid. The harsher environment and shorter growing season at the higher elevation (8,200 ft) are probably major contributing factors.

n) Aspen (Grid F) - Although the same species were captured in aspen as in Douglas fir, the individuals captured were more equally distributed among the species and average species diversity was higher at the aspen grid (0.491-1.245). The red-backed vole revealed an affinity for this type.

Total vegetation cover was higher in aspen than in Douglas fir and percent relative abundance (5.1%) was higher. However, other factors at the higher elevations including length of the growing season, harshness of the environment, vegetation species composition and tolerance range of small mammals to these factors, may be as important to small mammal abundance (and diversity) as vegetation cover.

2) Small Mammal Species Distribution and Abundance - The ecological distribution and abundance of each small mammal species encountered during trapping operations is defined below. Species macrohabitat affinities, average weights, Jolly-Seber estimates of density and other population parameters including immigration and survivability, and average range lengths (an indicator of home range size) are also provided. The Jolly-Seber procedure can be applied to multiple capture-recapture data when the population is subject to possible death, recruitment, immigration or permanent emigration during or between sampling periods (Cormack, 1968). The general model also allows for accidental deaths due to trapping, marking or handling. Reliable Jolly-Seber and range length estimates require sufficient recapture data for individuals of a species. Accordingly, these estimates are provided only for the least chipmunk, Colorado chipmunk, deer mouse, golden-mantled ground squirrel and the red-backed vole species captured on the larger (1.35 and 7.29 ha) grids. Information on reproductive effort and food preferences obtained from least chipmunks, deer mice and long-tailed voles collected in

major vegetation types during removal trapping operations is also presented in the following discussion. Tables on average weights, Jolly-Seber estimates, average range length, reproductive effort and food preferences can be found in the Second Annual Report (RBOSP, 1976).

a) Merriam's Shrew (*Sorex merriami*) - Shrews are live trap shy mammals and are only occasionally captured in Sherman traps even if locally abundant. Only one shrew, a Merriam's shrew, has been captured to date during live trapping operations. The specimen was taken on grid D (sagebrush) during October, 1974. Obviously, lack of data precludes formulation of definite conclusions concerning the distribution of this species within the study area.

However, the Merriam's shrew had never been reported from the Piceance Basin prior to this capture (Robert B. Finley, National Fish and Wildlife Laboratory, personal communication). According to Lechleitner (1969) and Armstrong (1972), little is known of the habits of this shrew and nowhere does it seem to be abundant. The latter author reported that the shrew is taken most often in grasslands, open woodlands, and areas where sagebrush is the predominant vegetation.

b) Thirteen-lined Ground Squirrel (*Spermophilus tridecemlineatus*) Only 12 thirteen-lined ground squirrels accounting for 0.44% of the total small mammal abundance have been captured during live trapping operations. This diurnal species showed a definite habitat affinity for the sagebrush stands on 84 Mesa as all captures occurred on the grid established in this type (grid 2). The species was not represented in either October or December, 1974 samples. The thirteen-lined ground squirrel spends the winter in a deep state of hibernation (Lechleitner, 1969) and was probably in early stages of this hibernation in mid-October, 1974.

Average weight for this species ranged from 58 to 94 g; values much lower than those reported by both Armstrong (1972) and Lechleitner (1969).

c) <u>Golden-Mantled Ground Squirrel (*Spermophilus lateralis*)</u> - The golden-mantled ground squirrel accounted for 5.4% of the total small mammal abundance and was the third most commonly encountered species during trapping operations. Although this diurnal species was captured in eight different habitats, it showed a definite affinity for only two types; pinyon-juniper/south slope (grid B) and pinyon-juniper/north slope (grid C). Armstrong (1972) supports this contention as he notes that relatively open woodland (e.g., pinyon-juniper stands) and forest edge communities are preferred golden-mantled ground squirrel habitat. As with most ground squirrels, it was inactive during the winter.

A sufficient number of recaptures of individuals of the species permitted the estimate of Jolly-Seber population parameters after certain trap nights for grid B (pinyon-juniper/south slope) and grid C (pinyon-juniper/north slope). On grid C (pinyon-juniper/north slope) estimated population densities increased from May to July, 1975 (0.3 - 1.0 individuals/ha). The increase does not appear to be the result of recruitment of young animals since no juveniles were captured on grid C during July, although juveniles were encountered in other habitat types during the sampling period. The increase may be an artifact of sampling; the result of increased trapping success of golden-mantled ground squirrels during July, and not the result of a greater number of animals.

Average extended range length for this species is reported for grids B and C. As only individuals captured at least at three different locations during any one sampling period were used in the analysis, sample sizes were low. However, the golden-mantled ground squirrel did appear to have the largest home range, as indicated by average range length (146.2 - 167.5 m), of any rodent sampled during trapping operations. It was also one of the largest rodents (158.5 - 176 g). Since large animals require more energy for their maintenance, they usually must range over larger areas to obtain it than smaller animals with otherwise similar food requirements.

d) Least Chipmunk (Eutamias minimus) - The least chipmunk, represented in samples from every grid, accounted for 40.8% of the total small mammal abundance and was the second most abundant species encountered during trapping operations. Although well represented in many grid samples, this diurnal species was captured most frequently on grid 5 (mixed brush) (13.8 individuals/100 trap nights).

The least chipmunk is the most abundant Colorado sciurid and has the widest ecological range of any sciurid in the State. It ranges from 6,000 ft to 12,000 ft in western Colorado and utilizes a variety of habitats from sagebrush plains to coniferous forests (Lechleitner, 1969). Within the area of investigation, the least chipmunk showed a definite affinity for five habitat types (i.e., sagebrush, rabbitbrush, pinyon-juniper/mixed brush, mixed brush and greasewood-sagebrush) all characterized by a high shrub cover.

Like the golden-mantled and thirteen-lined ground squirrels, no least chipmunks were captured in live traps during the winter. Unlike the ground squirrels, however, the least chipmunk is not a true hibernator. However, it does enter periods of torpidity during cold weather and is generally inactive during the winter (Lechleitner, 1969).

Jolly-Seber population estimates were possible on all large grids for the least chipmunk. Density estimates were consistently the highest on grid A (greasewood-sagebrush)(1.3-12.5 individuals/ha) and lowest on grids F (Douglas fir)(0.6 - 1.5 individuals/ha) and G (aspen) (0.9 - 1.1 individuals/ha). Armstrong (1972) reported that this species avoids dense unbroken forest which explains the low densities in Douglas fir and aspen.

Average extended range lengths derived for least chipmunks showed a lack of consistently large sample sizes. The inconsistancy prevents the identification of any causal relationships between habitat type or seasons and home range. However, it is widely recognized that home ranges in habitats of low productivity may be larger for a particular species than in more productive habitats (Pianka, 1974). The least chipmunk does have a smaller range than the golden-

mantled ground squirrel (113.6 - 131.9 m), as might be expected from its smaller body size (32.8 - 34.4 g).

The results of the analysis of stomach contents showed the least chipmunk was mainly a seed-eater throughout most of the year. However, during the early spring, when seeds are not readily available and succulent vegetation is abundant, the latter food item was utilized more extensively.

Reproductive status data for female least chipmunks collected during May, July, and October, 1975 show a single annual period of reproductive activity corresponding temporally to the males' breeding period (Skryja, 1974). The fact that 43% of the females examined in May were reproductively active, that no juveniles were trapped in May, and that juveniles were present in July live captured samples suggests the height of least chipmunk reproductive activity occurs prior to mid-July. The average litter size for least chipmunks, as reflected by the number of embryos ranged from 3-7 with a mean of about 6.

3) Colorado Chipmunk (Eutamias quadrivittatus) - The Colorado chipmunk was the fifth most abundant small mammal captured, comprising 3.14% of the total abundance. Its distribution was limited to pinyon-juniper woodlands as it was only represented in samples from grid B (pinyon-juniper/south slope), grid C (pinyon-juniper/north slope), and grid 4 (pinyon-juniper/mixed brush). This diurnal species was most abundant on grid 4 (1.67 individuals/ha) but exhibited definite affinities for all three types. Warren (1942) reported that the Colorado chipmunk can range from 4,200 ft to 10,500 ft elevation and typically inhabits areas of broken rocks and open coniferous woodland.

Expectedly, the Colorado chipmunk was not captured during the winter. Jolly-Seber population estimates for grids B and C were calculated. However, insufficient recapture data did not permit the estimation of population parameters

for many trap nights and thus formulation of definite conclusions concerning these estimates is precluded at this time.

As evidenced by weight and range length data, the Colorado chipmunk is slightly larger (48.2 - 53.1 g) than the least chipmunk and has a larger home range, (29.9 - 162.1 m).

f) Deer Mouse (Peromyscus maniculatus) - The deer mouse was the most frequently encountered small mammal during trapping operations accounting for 41.65% of the total captures. This nocturnal species was captured in all habitat types but was most abundant in rabbitbrush (grid 3) (13.64 individuals/100 trap nights). Its habitat preferences were similar to those of the least chipmunk in that it showed an affinity for habitat types with a high shrub cover.

Jolly-Seber population estimates show that the highest densities for the deer mouse occurred on grid A (greasewood-sagebrush)(2.4 - 8.0 individuals/ha). It also occurred at high population levels on grid E (mixed brush) (0.9 - 7.7 individuals/ha). Both of these grids are characterized by a high shrub cover (39.9% and 74.4 % cover, respectively).

Brown (1967) found the deer mouse to be most abundant in sagebrush and mountain mahogany communities in southeastern Wyoming. He suggested that these vegetation types produce large quantities of seeds suitable for consumption by deer mice. Larrison and Johnson (1973) reported deer mice to be the most abundant rodent in disturbed sagebrush and shadscale communities in Idaho.

The species commonly occurs at all elevations in Colorado from low meadows to alpine tundra (Warren, 1942) and is the most abundant of all Colorado mammals (Armstrong, 1972). Williams (1955), in surveying mouse and shrew distribution in central Colorado during the summer, found the deer mouse to be common in all montane communities sampled above 8,700 ft elevation, and most abundant on disturbed areas some of which were above 9,600 ft elevation. Brown (1967) rarely captured deer mice in spruce-fir forests but found them common in aspen stands in the Medicine Bow Mountains of Wyoming.

Average extended range lengths were calculated for the deer mouse. As with the least chipmunk, samples sizes were not consistently sufficient to ascertain the relationship between habitat and home range or determine if an inherent sex difference existed in the size of the home range. However, one unexpected trend was indicated by these data. Although deer mouse body weights averaged less (16.6 - 21.5 g) than the least chipmunk's, its average range length for most sampling periods (83.0 - 124.9 m) was comparable to the chipmunk's. This trend is contradictory to that established by the data for other species (golden-mantled ground squirrel, Colorado chipmunk, and least chipmunk) with sufficient range length data. Thus, it appears that although the deer mouse required less energy and matter than the chipmunk by virtue of its smaller size, it searched just as far to find it.

The results of the analysis of stomach contents of deer mice collected during removal trapping indicated that like the least chipmunk, the deer mouse is primarily a seed eater. It is active the year around and appears to utilize seeds more extensively during the winter when succulent vegetation is limited. Although the deer mouse did not appear to utilize succulent vegetation as often as the least chipmunk, it appeared to be slightly more omnivorous in its food habits. Jameson (1952), in a study of the food preferences of this species in California, found that they used a wide variety of foods. In the vicinity of Tract C-a, they were the only species of the three whose stomachs were examined that utilized invertebrates or vertebrates (probably carrion) to any extent.

Most females examined in May were reproductively active, all were active in July and 50% were active as late as October. King (1968) reported that deer mice may experience a breeding season as long as six months and have up to 3 litters in one season. A similar length breeding season and number of litters appears to be evident here.

Average litter size, again as indicated by the average number of embryos, ranged from 4.5 to 6.7 with a mean of about 5.5. This is consistent with

litter size of deer mice reported by Brown (1966) in a study in the Laramie Basin of Wyoming.

g) Piñon Mouse (Peromyscus truei) - Only 27 piñon mice were captured during all trapping periods and these accounted for less than 1% of the total small mammal captures. Its distribution was limited to pinyon-juniper woodlands as it was only captured at 2 grids, grid B (pinyon-juniper/south slope) and grid C (pinyon-juniper/north slope). It was captured more frequently on grid B (0.64 individuals/100 trap nights) but showed definite affinities for both habitats.

In Colorado, this species is noted as being common only in pinyon-juniper below 7,000 ft elevation (Lechleitner, 1969) but has been reported as an uncommon occurrence in pinyon-juniper up to 8,500 ft elevation in western Colorado (Armstrong, 1972). Douglas (1969) indicated that the piñon mouse is generally restricted to pinyon-juniper woodlands because it is dependent on the juniper for nesting sites and juniper berries as its preferred winter food.

According to average weight data for this species it appears to be slightly larger (18.5 - 25.0 g) than its congener, the deer mouse.

h) Bushy-Tailed Woodrat (Neotoma cinerea) - The bushy-tailed woodrat was the seventh most frequently encountered small mammal during trapping operations. This nocturnal species was captured on three different grids, grid B (pinyon-juniper/south slope), grid C (pinyon-juniper/north slope), and grid D (sagebrush). Most of the woodrats were captured on grid B (0.83 individuals/100 trap nights) and the species showed a definite affinity for that area.

The species was not captured during the winter sampling period though Lechleitner (1969) reported that this woodrat does not hibernate.

Bushy-tailed woodrat nests were frequently seen throughout the study area in crevices in vertical cliffs or other high rock outcrops. However, the species

may select den sites in a variety of locations (Lechleitner, 1969). On grid B (pinyon-juniper/south slope), where bushy-tailed woodrats were most frequently captured, nest sites were most often observed at the base of live juniper trees. Stones (1960) examined 233 woodrat houses in west-central Utah and found that 90% were in direct association with live junipers.

Average weights for this species indicate that the bushy-tailed woodrat was the largest small mammal species in the study area with adult body weights ranging from 130 - 200 gm.

i) Red-Backed Vole (Clethrionomys gapperi) - The red-backed vole was one of four vole species encountered during trapping but was the most abundant vole, accounting for 3.6% of the total number of small mammals encountered. The species was captured on three grids, grid E (mixed brush), grid F (Douglas fir), and grid G (aspen), all above 8,000 ft elevation. Armstrong (1972) stated that this boreal forest species is usually confined to well-developed coniferous zones from 8,000 to 11,000 ft in Colorado. Williams (1955) found the red-backed vole to be abundant in lodgepole pine forests in central Colorado and Brown (1967) reported this speices to be very numerous in spruce-fir forests, common in lodgepole pine and present, but in fewer numbers, in aspen in southeastern Wyoming. However, in the Piceance Basin, the red-backed vole was encountered more frequently in aspen but indicated definite affinities for both aspen and Douglas fir.

Average weights indicate that along with the sagebrush vole, the red-backed vole wasthe smallest of the vole species (14.0 - 22.1 g) captured during trapping operations.

j) Montane Vole (Microtus montanus) - Only 5 montane voles were captured during trapping operations accounting for only 0.9% of the total small mammal abundance. Although the species was captured in 3 different habitat types, the majority of the captures occurred on grid 1 (bottomland meadow) (0.51 individuals/100 trap nights). Williams (1955) captured montane

voles in a stream bottom and grazed meadow communities in central Colorado. Brown (1967) likewise found this vole to be common in grassy meadow situations in southeastern Wyoming.

The montane vole was captured during all sampling periods except number 5, September-October, 1975.

Average weights for the montane vole indicate this vole was the largest of the four voles (18.0 - 29.5 g) captured to date during trapping operations.

k) Long-Tailed Vole (Microtus longicaudus) - The long-tailed vole was the second most frequently captured vole species accounting for 1.4% of the total small mammal abundance. The species was captured in five different habitat types but was most often caught on grid A (greasewood-sagebrush) (0.98 individuals/100 trap nights) and shows a definite affinity for this habitat type. The long-tailed vole inhabits a variety of habitat types in Colorado, from wet meadow to dry rocky slopes (Warren, 1942) and has a wide altitudinal range, from below 5,000 ft elevation to above timberline in western Colorado (Armstrong, 1972). Armstrong (1972), however, reported that this vole is most abundant in streamside meadows with a thick ground cover. Durrant and Robinson (1962) found this species to be common in brushy meadows with a sparse herbaceous stratum in southwestern Colorado, suggesting that the long-tailed vole is not as dependent on dense ground cover as is the montane vole. Brown (1967) found the long-tailed vole to be common in meadow and bog situations and in aspen forests but absent from sagebrush and mountain mahogany communities in southeastern Wyoming.

The long-tailed vole was represented in samples from every trapping period. Average weights show this vole was larger (19.4 - 26.0 g) than the red-tailed and sagebrush vole but slightly smaller than the montane vole.

As indicated by food preference data, long-tailed voles are primarily herbaceous feeders and took advantage of succulent foods almost exclusively when available (Rieve, 1973). During May, when succulent foods were scarce

at high elevations, and late summer, the long-tailed voles utilized seeds to a greater extent.

The reproductive status of female long-tailed voles collected during May, July, and October, 1975 from the aspen vegetation type indicate peak reproductive activity for voles inhabiting aspen communities occurred during July as none of the females examined in May were active, all were active in July and 50% were active in October. Female long-tailed voles, like most of the rodents in the study area, are polyestrous (capable of more than one litter in a season). Average litter size appeared to be about 4.5. This is consistent with litter sizes reported for the long-tailed vole by Lechleitner (1969).

l) Sagebrush Vole (Lagurus curtatus) - Only 22 sagebrush voles were captured during live trapping operations which accounted for 0.8% of the total small mammal captures. The species was trapped most often on grid D (sagebrush) (0.30 individuals/100 trap nights) and grid E (mixed brush) (0.45 individuals/100 trap nights) and showed a definite affinity for both of these habitat types. It was also captured on grid 1 (bottomland meadow) during October and December, 1974. Sagebrush voles are usually associated with arid situations in Colorado (Lechleitner, 1969) and are generally limited to stands of sagebrush mixed with other shrubs up to 9,000 ft elevation in Rio Blanco County (Armstrong, 1972). Larrison and Johnson (1973) found the sagebrush vole to be present in small numbers only in sagebrush and crested wheatgrass communities in Idaho.

As are all the vole species encountered during trapping, the sagebrush vole is active throughout the year.

Average weights indicate that the sagebrush vole was one of the smallest of the vole species (17.8 - 19.8 g) captured during trapping operations.

m) Apache Pocket Mouse (Perognathus apache) - The Apache pocket mouse was one of the less commonly trapped small mammal species during trapping operations and accounted for only 0.44% of the total captures.

Although this nocturnal species was captured at five different grids, it was caught more frequently on two pinyon-juniper sites, grid 6 (pinyon-juniper/sagebrush 0.45 individuals/100 trap nights) and grid B (pinyon-juniper/south slope) 0.19 individuals/100 trap nights), and showed an affinity for both of tnese types. Armstrong (1972) reported that Apache pocket mouse generally inhabits sandy sites where burrows are constructed beneath low brush or cactus. Douglas (1969) captured this species in a burned-off pinyon-juniper woodland in Colorado.

Although the Apache pocket mouse was neither represented in December, 1974 nor in October, 1974 samples, Lechleitner (1969) reports that the species does not hibernate.

Average weights indicate that except for the masked shrew, the Apache pocket mouse was the smallest small mammal species (9.2 - 14.0 g) captured during live trapping operations.

3) Seasonal Variations in Small Mammal Abundance - The highest trapping success occurred during sample period 1, October, 1974, when an average of 15.39 individuals/100 trap nights was recorded. Small mammal populations are generally at their peak levels in late summer following the breeding period. This was evidenced by a high trapping success during October for most of the species, the notable exception being the golden-mantled ground squirrel and the thirteen-lined ground squirrel. However, these species are true hibernators (Lechleitner, 1969) and had probably entered a state of reduced activity corresponding with the onset of cooler days and longer nights. Although not true hibernators, the least and Colorado chipmunks may stay in their burrows for extended periods during cold weather, sometimes in a torpid state. During this time, they may utilize stored foods gathered during more favorable times thus eliminating the need to forage during winter (Lechleitner, 1969). Due to the absence of thes ground squirrel and chipmunk species, trapping success (5.37 individuals/100 trap nights) was greatly reduced during the December, 1974 sampling period.

Although all species were represented in the May, 1975 samples, total abundance (12.71 individuals/100 trap nights) as indicated by trapping success was reduced from October, 1974 samples. Most small mammal populations existing in cooler climates are undoubtedly somewhat reduced by overwinter mortality. The extent of the overwinter mortality is indicated by the Jolly-Seber parameter 0, the probability an animal alive at time i survives to time i+1, estimated for those species on the larger grids with sufficient recapture data. In almost all instances, this parameter was the lowest for trap night 5, indicating low probability of survival from October, 1974 to May, 1975. Also, although some small mammals may have been at their height of reproductivity during late May, recruitment of juveniles into the active foraging population did not occur until later in the summer. This is evidenced by the trapping results provided for each species. Juveniles of only three species, the deer mouse, golden-mantled ground squirrel, and Apache pocket mouse, were captured during May. Thus, the effects of overwinter mortality coupled with the absence of newly recruited juveniles were probably the main reasons for the reduced small mammal population levels indicated in May.

As indicated by the reproductive status of female least chipmunks, deer mice, and long-tailed voles, most small mammal species were probably near their height of reproductive acitvity during July. Correspondingly, juveniles of practically all species were caught in July grid samples. Therefore, an increase in trapping success would be expected in July, not a decrease as indicated by the data (11.37 individuals/100 trap nights in July versus 12.71 in May).

However, in this instance trapping success was probably not a good indication of total small mammal population levels. During July, productivity is high and food is abundant. Therefore, baiting materials were probably not as attractive to small mammals as during other periods when food was not as plentiful. The result was a decrease in number of animals attracted to the traps and a corresponding decrease in trapping success.

By October, most of the species were finished or nearly finished reproducing and many new juveniles were present in trapping samples. Natural foods were less abundant than in July and most small mammals were probably again attracted to peanut butter, oats, and cracked corn. The result, as expected, was an increase in trapping success (14.52 individuals/100 trap nights). In fact, small mammal population levels in October, 1975, as indicated by trapping success, were comparable to the levels found during October, 1974 sampling.

b. Pitfall Trapping - To insure that all small mammal species present in the vicinity of Tract C-a were inventoried, pitfall traps were established in all major vegetation types. These traps are designed to capture live-trap shy small mammals, or those not attracted to the peanut butter-oats-cracked corn bait used in live trapping.

To date, only one small mammal species not documented by live trapping methods has been captured in pitfall traps. The masked shrew (*Sorex cinereus*) was captured in greasewood-sagebrush (pitfall A) during October and December, 1974 and in sagebrush (pitfall D) during October, 1974. However, one vole and two shrews were caught during October, 1975 pitfall trapping operations, which have not been positively identified. This is presently being done by Dr. Robert B. Finley, a mammalogist with the National Fish and Wildlife Laboratory.

The northern pocket gopher has been captured both in pitfall traps (May, 1975) and live traps (May and July, 1975) on the bottomland meadow grid. This gopher, as other pocket gophers, is highly specialized for a fossorial life and spends the majority of its time underground (Lechleitner, 1969). This species has the broadest geographic and altitudinal range of Colorado pocket gophers. It also has the broadest ecological tolerance, occurring in greatest numbers on deep sandy soils, but colonizing heavy clays and coarse, gravelly soils as well (Armstrong, 1972).

The masked shrew is the second shrew species that has been documented to date in the study area. The other species, Merriam's shrew, was captured in a live trap on grid D (sagebrush) during October, 1974. Shrews are highly in-

sectivorous (Lechleitner, 1969) which may account for the low incidence of captures in live traps.

Although all specimens of the masked shrew were taken in well-drained, predominantly sagebrush stands, both Armstrong (1972) and Lechleitner (1969) reported that this species is most commonly found in moist habitats within coniferous forests. It is expected therefore that the as yet unidentified shrew taken from the pitfall established in aspen vegetation will also be a masked shrew.

c. Night Spotlight Census - The night spotlight census was conducted on the nights of November 11 and 13, 1974, February 10 and 12, June 22 and 25, and October, 19, 1975. Only one night of the spotlight census was performed during October, 1975 because of unfavorable weather conditions and the onset of mule deer hunting season.

This method of censusing nocturnally-active animals, especially lagomorphs, has proven valuable in short-grass plains situations but encounters problems of visibility in the Piceance Basin due to the dense vegetation and varied terrain. A modification of the standard method helps to account for the decreased visibility.

The presence of at least three species of lagomorphs has been documented to date on or near Tract C-a. The white-tailed jackrabbit (*Lepus townsendii*) and the black-tailed jackrabbit (*L. californicus*) were easily identified by field observation, but the cottontail (*Sylvilagus* sp.) is much more difficult to distinguish to species. A specimen was collected by ECI personnel and identified by Dr. Robert B. Finley of the National Fish and Wildlife Laboratory as a Nuttall's cottontail (*Sylvilagus nuttallii*). However, it is possible that more than one species of cottontail reside in the study area. Two lagomorph species (cottontail and white-tailed jackrabbit) and the porcupine (*Erethizon dorsatum*) were observed during night spotlight censuses conducted thus far.

The white-tailed jackrabbit occurs on the plains and in open areas within the Colorado mountains where it feeds primarily on herbaceous material during spring, summer, and fall, but consumes more shrubs during the winter (Lechleitner, 1969). It has been observed on the Tract C-a study area in the upland sage vegetation type of the 84 Mesa and among sparse sage or on open grassy areas of Cathedral Bluffs. The black-tailed jackrabbit has been observed, and a specimen taken, on the mowed hay field near the 84 ranch. This jackrabbit is smaller than the white-tailed jackrabbit and characterized by a black dorsal strip extending from the tail onto the rump; its winter pelage is never white as in the case of the white-tailed jackrabbit (Lechleitner, 1969).

Nuttall's cottontail or the mountain cottontail is the only cottontail species identified from specimens taken to date. It inhabits edge situations at elevations ranging from 6,000 to 11,000 ft and feeds on a variety of grasses, sedges, forbs, and shrubs (Armstrong, 1972; Lechleitner, 1969). The desert cottontail, which may also be present in the Tract C-a area, characteristically occurs at elevations below 7,000 ft and may cohabit the mountain valleys of western Colorado with Nuttall's cottontail (Lechleitner, 1969).

Lagomorph population estimates and general field observations indicate that current lagomorph populations are low. Data gathered by Colorado Division of Wildlife personnel across western Colorado support this finding and show that lagomorph populations reached their cyclic low during 1974 after having reached a high plateau during 1970. Populations are expected to increase during the next few years (Claude White, Regional Game Management Biologist for the Colorado Division of Wildlife, personal communication, 1975).

The porcupine (*Erethizon dorsatum*) is a large, stout-bodied rodent, semi-arboreal in habit, which feeds primarily on the leaves, bark, buds, and twigs of both deciduous and coniferous trees. They sometimes eat forbs and grasses as well (Lechleitner, 1969). Trees stripped of bark provide evidence of the presence of porcupines in many of the pinyon stands in the Tract C-a study area.

d. Bat Investigations - Mist netting for bats took place on four consecutive nights in June and on four consecutive nights in August, 1975. One or two nets were operated each night and over both periods a total of four locations were sampled. At three of these locations, the nets were placed over stock tanks and at the fourth location, the net was placed over a small shallow pond. Five bat species have been captured to date.

In June, the long-eared myotis (*Myotis evotis*) and the small-footed myotis *M. leibii*) were captured at two stock tanks in bottomland sagebrush habitats. The small-footed myotis is known to occur in a variety of situations throughout the state and to over-winter in Colorado as well (Armstrong, 1972). The long-eared myotis occurs in sparse coniferous forests and semiarid shrublands in western Colorado, and migrates out of the state in winter (Armstrong, 1972).

In August, four bat species were captured in one of the same bottomland sagebrush locations sampled in June. In addition to the two above-mentioned bats, the California myotis (*Myotis californicus*) and the big brown bat (*Eptesicus fuscus*) were netted over this stock tank in August. The California myotis is a species of western North America and occurs only in western-most Colorado at lower elevations (Armstrong, 1972). The big brown bat is one of the most common bats in Colorado as well as in the United States. This species is well adapted to human habitation, roosting most often in man-made structures; and like the small-footed myotis, the big brown bat overwinter in the state (Lechleitner, 1969).

Also during August sampling, a hoary bat (*Lasiurus cinereus*) and a small-footed bat were captured at a small pond located near a dense stand of rabbitbrush below the Stake Springs impoundment. The hoary bat is much larger than any of the *Myotis* species and occurs statewide at lower and middle elevations, but nowhere appears abundant (Lechleitner, 1969).

Large, solitary bats have been observed in flight on Cathedral Bluffs (elevations up to 8,500 ft) during mammal night spotlight censuses. However,

our attempt to mist net any of these bats over a stock tank near the top of the bluffs in August was unsuccessful. Dr. Robert B. Finley of the National Fish and Wildlife Service (personal communication) has been mist netting bats in the area and suspects from his captures north and east of Tract C-a that the hoary bat would occur predominantly at the higher elevations of the study area near coniferous forests. The silver haired bat (Lasionycteris noctivagans) and the big brown bat may also appear at these higher elevations on Cathedral Bluffs.

For complete tabulated results and figures of all small mammal studies see pages 3-7-311 through 3-7-488 in the Second Annual Report (RBOSP, 1976).

4. Discussion - The presence of 28 species of small (and medium-sized) mammals has been documented by live, removal, and pitfall trapping, night spotlight censusing, mist netting (for bats) and opportunistic observations in the vicinity of Tract C-a. Data collected during live-trapping operations from over 2,700 individuals, comprising 13 small mammal species, have permitted the formulation of several generalizations concerning the distribution and abundance of small mammal populations among major habitats within the area of investigation. Although these generalizations were drawn from live-trapping data, the generalizations are not necessarily restricted to live-trappable small mammals but are probably applicable to all small (and medium-sized) mammals encountered except, of course, bats.

Small mammals ultimately depend upon vegetation for food, shelter, and in some cases, as their only supply of water. Consequently, vegetation, specifically the amount and kind of vegetation, was the most important factor controlling the distribution and abundance of small mammal populations in the vicinity of Tract C-a. Elevation appeared to be important also especially for some species.

Within habitats sampled below 8,000 ft elevation, the amount of shrub cover appeared to be the most important factor regulating the abundance of small mammals. The largest number of small mammals captured per unit trapping

effort (i.e., individuals/100 trap nights) occurred on grid 3 (rabbitbrush , 12.17) followed in order by grid A (greasewood-sagebrush , 9.98) and grid 5 (mixed brush, 5.52). Vegetation data collected from permanent phytosociological transects on or near small mammal grids showed that these grids also exhibited the highest shrub cover of all grids below 8,000 ft (35.5, 39.9 and 74.4%, respectively). Accordingly, the grid with the fewest captures below 8,000 ft, grid 1 (bottomland meadow, 4.65 individuals/100 trap nights), also exhibited the lowest shrub cover (0.3%).

Although the same trend holds true for grids above 8,000 ft, i.e., more small mammals are encountered in habitats with a higher shrub cover, total small mammal abundance is lower for these grids than for those at lower elevations. This is undoubtedly due to the harsher conditions and shorter growing season at the higher elevation.

Species diversity, as indicated by the Shannon-Weiner index which accounts for both number of species and number of individuals of each species, seems to be tied closely to the presence or absence of trees (i.e., pinyon-juniper) in habitats below 8,000 ft. Of the larger (7.29 ha) grids, the two that consistently showed the highest diversity were the two established within pinyon-juniper woodlands, grid B (pinyon-juniper/south slope) and grid C (pinyon-juniper/north slope). Likewise, grid 4 (pinyon-juniper/mixed brush) had the highest species diversity for the 0.81 ha grids. Pinyon and juniper trees provide food for many small mammal species that eat the highly nutritious pinyon nuts and juniper berries. The latter are more consistently available than pinyon nuts as they remain on trees a large part of the year and are not so completely destroyed by insects as pinyon nuts (Frischknecht, 1975). The cambium of pinyon may also be eaten by certain species and the shreddy bark of juniper is often used in nest building (Frischknecht, 1975).

The value of pinyon and juniper trees as a source of food and potential nesting sites is further emphasized when it is noted that 8 of the 13 species encountered during all live-trapping operations inhabited pinyon-juniper woodlands. In fact, three of the species, piñon mouse, Colorado chipmunk, and the

bushy-tailed woodrat, were generally limited to this vegetation type. Another species, the golden-mantled ground squirrel, was caught almost exclusively on grids established within or adjacent to pinyon-juniper woodlands.

At elevations above 8,000 ft, the harshness of the environment -- not the presence or absence of trees -- is probably the primary determining factor in the distribution of small mammals. Of the 13 species encountered, only 5 were captured in grids established at the higher elevations. Furthermore, only 1 trappable small mammal species, the red-backed vole, is adapted to the environmental extremes of the higher elevations (Lechleitner, 1969).

The two most abundant small mammal species within the vicinity of Tract C-a are the least chipmunk and the deer mouse. Both were represented in samples from every grid and together accounted for 82.5% of the total small mammal abundance. The habitat affinities of the least chipmunk and the deer mouse as indicated by chi-square values, were almost identical as both species were caught more frequently in habitat with a high shrub cover.

The golden-mantled ground squirrel, though not nearly as abundant as either the least chipmunk or the deer mouse, was the third most frequently captured small mammal accounting for 5.4% of the total abundance. This species indicated a definite affinity for pinyon-juniper woodlands as did three other species, the Colorado chipmunk, piñon mouse, and the bushy-tailed woodrat, discussed previously.

The other seven trappable small mammal species were captured rather infrequently and accounted for only 6.9% of the total abundance. However, some species were predominant in certain habitat types and a definite pattern of macrohabitat preferences was discernable for all.

Captures of the thirteen-lined ground squirrel were limited to the grid established in sagebrush vegetation on 84 Mesa, and accordingly, the species showed a definite affinity for this habitat. The Apache pocket mouse was captured within five different types but showed an affinity for pinyon-juniper

woodlands. Merriam's shrew, by virtue of its one capture in sagebrush, indicated an affinity for that type. This affinity, however, is substantiated by the literature (Armstrong, 1972).

Of the four vole species, the red-backed vole was the most abundant. It is adapted for living at elevations above 8,000 ft (Lechleitner, 1969) and was the predominant small mammal in both Douglas fir and aspen vegetation. The montane vole showed a definite affinity for bottomland meadow while its congener, the long-tailed vole, indicated an affinity for the thick greasewood-sagebrush-rabbitbrush stands characteristic of the bottomland drainages. The sagebrush vole, as its name implies, revealed a preference for sagebrush as well as for mixed brush.

Of the three species collected by removal trapping for analyses of stomach contents, two, the least chipmunk and the deer mouse, indicated preferences for seeds. However, both utilized succulent materials more frequently in the spring when new seeds were not yet abundant. The deer mouse was slightly more omnivorous in its food habits as invertebrate and vertebrate materials were occasionally observed in stomach contents. Long-tailed voles, collected within the aspen vegetation type, utilized primarily succulent materials. However, it too was opportunistic when its favored food was not available, since a high percentage of seeds was found in stomachs of specimens collected in early spring.

As indicated by both the proportion of juveniles in samples taken from each trapping period and reproductive data collected from least chipmunk, deer mouse, and long-tailed vole specimens, the peak of the reproductive activity for most of the small mammal species encountered appears to occur from May to July. Correspondingly, small mammal population levels are at their highest in late summer after the breeding season. Over-winter mortality results in population lows during early spring.

Several species of small and medium sized mammals not amenable to inventory by the live-trapping techniques employed were documented by other methods.

Pitfall traps, established in all major habitats, revealed the presence of the masked shrew.

A cottontail and two species of jackrabbits, the white-tailed jackrabbit and the black-tailed jackrabbit, as well as the porcupine, were seen during night spotlight censuses. The censuses confirmed information obtained from the Colorado Division of Wildlife that lagomorph population levels in the Piceance Basin are low.

The presence of two species of bats, the long-eared myotis and the small-footed myotis, were revealed by mist netting during June, 1975. Two more species, the California myotis and the hoary bat, were documented during August sampling.

B. Large Mammals

1. Objectives - Large mammal investigations are designed to determine the distribution and relative abundance of mule deer, elk, and feral horses in the vicinity of Tract C-a on a seasonal basis during a two-year baseline study. Migration patterns of mule deer in the study area is a further objective. The purpose of this report is to present, summarize, and interpret data gathered between October, 1974 and October, 1975; therefore, the objectives of this two-year program have not been completely satisfied or reported after this first year of study.

2. Methods

a. Data Collection - Aerial surveys are being conducted periodically throughout the year for all large mammal species. Pellet group counts are being employed to aid the evaluation of mule deer use of the area. During periods when seasonal movements of mule deer are occurring, aerial surveys and track counts are being conducted to determine migration patterns. Sex and age ratio counts were conducted after the 1974 deer hunting season.

For a more complete discussion of methodology used in large mammal studies, refer to pages 3-7-459 through 3-7-466 in the Second Annual Report (RBOSP, 1976).

b. Data Analysis - For specific methods and formulae used for large mammal data analysis, see pages 3-7-466 through 3-7-467 in the Second Annual Report (RBOSP, 1976).

3. Data Summary

a. Aerial Surveys - Two flights were conducted each month from November, 1974 through April, 1975 with the exception of January, 1975 when only one flight was completed.

The numbers of mule deer observed on four census areas during aerial surveys conducted from November, 1974 through April, 1975 are presented in Table 3-7-6. Mule deer were not observed in surveys conducted during June and August on the combined mule deer, elk, and feral horse counts.

As varied backgrounds, animal habits, weather and spotting conditions preclude the observation of all animals within a census area, results of aerial surveys do not represent the absolute number of animals present on the area during the survey periods. Gilbert and Grieb (1957) reported that an observer could consistently count a certain percentage of mule deer present in an area for a specific set of spotting conditions. Smaller percentages of the deer present were counted in surveys conducted when there were relatively poor spotting conditions. Spotting conditions rely on several factors including the amount of turbulence affecting the airplane, light intensity and direction, and characteristics of the background such as presence or absence of snow. Gilbert and Grieb (1957) reported that with excellent snow conditions, an average of 49% of the total deer present were counted, while an average of only 45% and 34% were counted during good and poor to fair conditions, respectively, when air and ground deer counts were compared. For the purposes of this study, spotting conditions from poor to excellent are defined as follows: excellent counting conditions are experienced when the entire area is completely covered by snow and the sky is clear; poor conditions are experienced when snow cover is sparse and the sky is cloudy; good and fair counting conditions range between the excellent to poor counting conditions and are based on the relative amount of snow cover and cloud cover.

Table 3-7-6

MULE DEER OBSERVED ON FOUR CENSUS AREAS DURING ELEVEN SURVEY PERIODS FOR RBOSP1/

Date of Census	Total Observed	Census Area			
		Tract C-a	East	West	North of Tract2/
November 8, 1974	33	14	7	12	--
November 21, 1974	3	0	1	2	--
December 9, 1974	179	12	103	64	--
December 30, 1974	295	60	105	130	--
January 14, 1975	111	33	62	16	--
February 1, 1975	125	24	95	2	4
February 12, 1975	119	30	75	0	14
March 4, 1975	244	7	229	0	8
March 13, 1975	324	14	296	0	14
April 3, 1975	258	24	220	4	10
April 14, 1975	500	12	469	0	19

1/ The figures represent only those animals observed within the census area boundaries.

2/ Censuses of this area commenced during February, 1975.

Mule deer were observed in small groups scattered throughout the census areas during the November surveys, which were conducted during poor to fair spotting conditions. The deer were observed in the mixed brush and sagebrush vegetation types on the West Census Area; in mixed brush, sagebrush, and pinyon-juniper vegetation types on Tract C-a; and most frequently in the pinyon-juniper vegetation type on the East Census Area.

The first survey in December was conducted during fair spotting conditions, but the second survey took place during excellent spotting conditions. The number of mule deer observed during this period exceeded the number observed during the November surveys, and the size of the individual groups of deer spotted also increased. Relatively large numbers of deer were observed in the mixed brush vegetation type on the West Census Area during the December period, particularly during the second survey of the month. The West Census Area was intensively surveyed with a helicopter three days before the December 30, 1975 survey and few deer were observed at that time, possibly indicating a rapid change in level of deer use within the study area. Several herds of deer were scattered within the pinyon-juniper and sagebrush vegetation types occurring on Tract C-a. The deer observed on the East Census Area were occupying the small gullies along the larger gulches and creeks.

Excellent to good spotting conditions were recorded on the January survey, but fewer deer were observed on all census areas compared to the December counts. The deer observed on the West Census Area were located in mixed brush and sagebrush vegetation types occupying the south-facing slopes of Dead Horse Ridge. Small groups of mule deer were observed on north-facing slopes and gully bottoms as well as on the south-facing slopes of Tract C-a. Deer were generally scattered throughout the East Census Area.

Excellent spotting conditions were experienced during the first survey conducted in February, 1975, but only fair spotting conditions were present during the second flight. The February survey flights over the West Census Area revealed very little deer activity; only two mule deer were observed and large portions

of the area were covered by undisturbed, trackless snow. Deer observed on Tract C-a were on the south-facing slopes above Dry Fork and on the ridge between Corral Gulch and Box Elder Gulch. The majority of the animals observed on Tract C-a during this period were in pinyon-juniper vegetation types, and the remainder were located in the sagebrush vegetation type. A similar distribution of mule deer among vegetation types was noted on the East Census area with observations in the pinyon-juniper type occurring more frequently than in any of the other vegetation types. Mule deer were concentrating in the small gullies and slopes near Yellow Creek in the northeast portion of the census area with other small herds scattered along Stake Springs Draw and Ryan Gulch. A survey of the area north of Tract C-a was initiated during February, 1975. Small herds of deer were observed scattered throughout the pinyon-juniper vegetation type in the North Census Area.

Deer were not observed on the West Census Area during the March surveys; few deer were observed on Tract C-a, but more deer were observed on the East Census Area than during previous surveys. Poor spotting conditions were experienced during the March surveys due to lack of fresh snow. The majority of the animals observed on Tract C-a were scattered along the ridge between Corral Gulch and Box Elder Gulch. Deer on the East Census Area appeared to be using the sagebrush vegetation type more heavily than in previous months. Most of the deer were concentrated in the sections comprising the northeast quarter of the census area. In the North Census Area the pinyon-juniper vegetation type appeared to be used more heavily than the other vegetation types during this period.

Poor and excellent spotting conditions were experienced for the April surveys. Few mule deer were observed on the West Census Area during this period. The mule deer observed on Tract C-a were between Corral Gulch and Box Elder Gulch, primarily in the pinyon-juniper vegetation type. Large herds of deer were observed in all sections of the East Census Area except those comprising the southwest quarter. The pinyon-juniper and sagebrush-covered areas north of Black Sulfur Creek and Ryan Gulch each had several groups of deer, but the largest concentration of deer was observed in the meadows along Corral Gulch

and Yellow Creek. Deer appeared to be dispersing from the concentration area on the northeast portion of the East Census Area across 84 Mesa north of Tract C-a.

The distribution and relative number of mule deer observed during the 1974-1975 surveys suggest that animal movement and distribution changes occurred in the study area throughout the winter. The general distribution pattern observed during the 1974-1975 winter was characterized by a few, small, widely-scattered groups throughout the area during the first part of the winter. Greater numbers of mule deer then concentrated into larger herds during December, 1974. A decrease in the number of deer was observed in early 1975. Concentrations of deer generally moved from the west to the east within the study area as winter progressed. Heavy use of the East Census Area continued throughout March and April of 1975. The West Census Area received only light use from January through April, 1975. Mule deer were observed on Tract C-a throughout all surveys.

The heaviest use of Tract C-a occurred during December, 1974 through February, 1975.

General observations and the literature indicate that mule deer use of specific areas often depends on climatic conditions. During severe windy winter weather, mule deer will seek relatively protected areas such as pinyon-juniper stands, very thick brush, or the lee side of ledges. During other times, the animals will generally bed near a tree or bush.

South-facing slopes and windblown ridges at the relatively higher elevations are used more frequently than the adjacent north-facing slopes and other areas often covered by deep snow. At lower elevations, where total snow fall is not so great, the animals seem to prefer north-facing slopes where better distribution of food and cover exists, relative to the adjacent south-facing slopes. In their search for food, mule deer seek areas which have a mixture of forage species.

Continual snow cover over much of the area throughout the winter precludes extensive use of grasses and forbs. During this period, the deer browse sagebrush, mountain mahogany, serviceberry, antelope bitterbrush, pinyon, and juniper.

During the spring the mule deer consume the grasses and forbs growing in the bottomland meadows to a greater degree than browse species which they consume throughout the winter.

A small number of elk has been observed on the study area during aerial surveys and general field observations. Elk were not observed on Tract C-a or in the East Census Area during the past year. Elk observed during the surveys conducted throughout the winter months were generally on windblown ridge tops or south-facing slopes along Cathedral Bluffs, north-west of Tract C-a. Animals south of Tract C-a along Ryan Gulch were observed during April, 1975. Those observed in the gulch bottoms southwest of Tract C-a were observed during the summer months.

Feral horse herds are common on the study area throughout the year. The number of horses observed during the six aerial elk and feral horse surveys conducted from October, 1974 through October, 1975 is presented in the following table. A large number of field observations of feral horses has been compiled by ECI personnel conducting other field investigations. This information, in addition to aerial survey data, was used to describe feral horse distribution.

NUMBER OF FERAL HORSES OBSERVED DURING SIX AERIAL SURVEYS
CONDUCTED FOR RBOSP FROM OCTOBER, 1974 THROUGH OCTOBER, 1975

	Horses Observed			
Date	Total	Adult	Juvenile	Unidentified
November 8, 1974	108	24	15	69
December 30, 1974	86	8	2	76
March 4, 1975	41	16	4	21
April 14, 1975	74	69	5	0
June 26, 1975	93	69	24	0
August 18, 1975	63	55	8	0

Surveys during November, 1974 revealed that the horses were distributed on the study area in herds of up to 19 individuals. The largest concentration of horses was observed near the landing strip in Section 9, T2S, R99W. Most of the horses in the study area were observed on ridge tops, although the horses observed on Tract C-a were on the slopes above the bottoms of the gulches. Few horses were observed near the landing strip during December, and the animals appeared to be more widely scattered in areas farther from the tract. Several herds were observed on the windblown ridges on top of Cathedral Bluffs. Poor spotting conditions prevailed during the March survey. Most of the horses were observed in sheltered areas and no large concentration of animals was evident. The largest herd spotted during March, 1975 was located on 84 Mesa.

The fourth feral horse survey was conducted on April 14, 1975. Most of the horses observed during this period were near Dry Fork and Corral Gulch, although a herd of 15-17 animals was located on the eastern portion of 84 Mesa at this time.

The June survey revealed most of the horses to be south and west of Tract C-a. The largest herds observed during this period were on the ridge between the Right and Left forks of Stake Springs Draw, although numerous animals were observed on Landing Strip Ridge, and in Water Gulch and Corral Gulch.

All of the feral horses observed during the August, 1975 survey were west of Tract C-a. A herd of 26 animals was observed on Landing Strip Ridge and the remaining horses were spotted in herds ranging in size from 5 to 9 individuals. The smaller herds were scattered on the ridge tops between Dead Horse Ridge and Airplane Ridge.

Results of studies indicated that the herd of horses observed on Landing Strip Ridge throughout the summer of 1975 was comprised of approximately 30 individuals, which included 21 adults and 9 juveniles. The animals in this herd appeared to range north of Box Elder Gulch and south of Right Fork of Stake Springs Draw as well as along Landing Strip Ridge. The horses in this general area appeared to be members of the largest herd on the study area. Over 50

individuals were observed near the landing strip on November 8, 1974. Observations of feral horses on 84 Mesa during mule deer winter counts and mule deer migration movement studies indicate that the herd fluctuated between 12 and 15 animals. This herd concentrated its winter activities east of the road which crosses 84 Mesa. Horses were not observed east of the road on 84 Mesa during the summer surveys, but herds ranging in size from 3 to 17 animals were observed west of the 84 Mesa road and north of Tract C-a. A small herd of feral horses has also been observed on Wolf Ridge, east of Tract C-a.

The feral horses observed on Tract C-a have generally been located near the boundary of the tract. Few horses have been reported over 0.81 km (0.5 mi) within the tract boundaries and these herds are usually comprised of less than eight individuals. The relatively frequent periods of human activity on the tract may have had an effect on the number and location of horses observed there.

Feral horses will water at springs, water impoundments and stock tanks throughout the area when the water is available. These areas are listed in section H (Domestic Livestock). Individuals within a "band" and the location of bands appear to fluctuate throughout the year. See Figure 3-7-50 in the Second Annual Report (RBOSP, 1976) for locations of feral horse bands observed during the various seasons. Horse movements are more restricted by the fences in the area than are mule deer movements.

The horses will seek shelter from severe winds and cold weather but do not appear to require as much protective cover as mule deer.

b. <u>Mule Deer Sex and Age Classifications</u> - Mule deer sex and age classification counts were conducted on December 27, 1974 over Tract C-a, the West Census Area, Stake Springs Draw, and 84 Mesa. The count indicated a buck:doe:fawn ratio of 18:100:92 based on the 7 bucks, 40 does, and 37 fawns (84 deer total) classified. Bartmann (1975a) reported a buck:doe:fawn ratio of 18:100:85 on the basis of 2,817 deer classified during post-hunting season 1974 counts conducted by the Colorado Division of Wildlife for the entire Piceance Basin Area.

c. <u>Mule Deer Migration Movement Study</u> - The spring mule deer migration movement study was conducted on April 12-26, 1975. Weather conditions on April 17-18 did not allow a flight to be conducted, so a total of six aerial surveys were conducted during the spring period. Track counts conducted on the road east of Tract C-a yielded additional information on mule deer movements during this period.

Larger numbers of mule deer were observed on the eastern portion of the study area during March and early April than were seen in preceding months, so the migration study was initiated in mid-April and continued through late April. Field observation forms subsequent to the termination of the surveys indicated that herds of deer still frequented the eastern portion of the study area during early May but had dispersed by mid-May.

Large numbers of deer were frequently observed in the bottomlands along Yellow Creek, Ryan Gulch, and Black Sulfur Creek during the morning aerial surveys. The animals appeared to concentrate in the meadows to feed, but bedded down in the more rugged shrub-covered hillsides nearby. Deer appeared to gradually drift away from the areas of high concentration used during the winter and spring, with small groups or individuals moving independently rather than a large group moving en masse to a summer range. The mule deer on the study area scattered westward during late April. Most portions of Tract C-a and the eastern portion of the area were used, at least by a few deer, during their slow drift toward summer range. Relatively few mule deer were observed west of Tract C-a during the migration survey period. Snow-covered areas were common on the higher elevations west of Tract C-a and the vegetation had not begun to produce new growth as it had on Tract C-a and the area east of Tract C-a. Field observations indicated that deer were in the area west of Tract C-a through most of May.

Much back and forth movement was recorded during the track count survey, possibly due to the proximity of the road to winter range, its location with respect to the daily feeding and bedding areas used during the period, and the meandering movement of the deer to summer ranges. Certain areas along the track count route appeared to be used more heavily than others during the

late April survey. The major drainages and associated areas of broken topography appeared to be most heavily used during the movement period. Relatively smaller amounts of use occurred on large, flat, sagebrush-covered areas or on north-facing slopes.

d) Mule Deer Pellet-Group Counts - Pellet-group plots were established on Tract C-a during October 21-24, 1974 and on the areas west of Tract C-a during May 16-19, 1975. The plots on Tract C-a were examined on May 20, 1975; pellet groups accumulated during the 1974-1975 winter were recorded and removed. All plots were re-examined during September 19-22, 1975, and pellet groups accumulated over the 1975 summer were recorded and removed.

A comparison of the pellet group index for the over winter 1974-75 accumulation period and for the over summer 1975 accumulation period (for Transects 1, 5, 6, and 7) on Tract C-a indicates the relative levels of deer use on the tract between the two periods. Although the confidence interval (see Table 3-7-206 in Second Annual Report; RBOSP, 1976) is wide for the over winter period, pellet groups were recorded on all transects with more groups occurring on the eastern transects and fewer groups occurring on the western transects. During the summer period, the transects on Tract C-a did not accumulate a single pellet group. This indicates that the level of deer use on the tract was extremely limited over the summer period.

The transects located off Tract C-a were established in the spring of 1975, therefore, only the summer's data are interpretable and seasonal comparisions are not possible at this time. The data indicate that, in order to estimate mule deer use within 20% of the mean at the 90% confidence level by sampling pellet group accumulation, the intensity of the sampling program would have to be increased over six-fold. The limitations of pellet-group data for estimating relative use of areas, the wide dispersion of mule deer during the summer, and the relatively low intensity of mule deer use of Tract C-a during the summer do not warrant such an increase at this time under the scope of the present studies.

General conclusions concerning mule deer habitat use of the area west of Tract C-a are suggested on the basis of pellet group data which have been gathered. All of the transects except one indicated deer use during the summer months. The transect which did not reveal deer activity was located south of Tract C-a in pinyon-juniper and sagebrush vegetation types. Ninety-two percent of the total pellet groups recorded after summer, 1975 were located in mixed brush vegetation type, while the remaining groups were recorded in the sagebrush vegetation type. The mixed brush vegetation type occurred on less than half of the plots sampled.

The relative distribution of the pellet groups recorded after summer, 1975 by slope gradient indicated forty-two percent of the pellet groups occurred on slopes of 0-10° compared with 21% on slopes of 11-20°, 16% on slopes of 21-30°, 5% on slopes of 31-40° and 2% on slopes greater than 41°. Thus it appears that relatively more pellet groups occurred on the slopes of 21-30° than would be expected based on the relative number of plots located in each slope gradient class. The data were not tested for significant differences due to the limited number of pellet groups observed.

The relative distribution by slope aspect of pellet group accumulation over summer, 1975 indicated the number of pellet groups observed was so limited and the groups were distributed over the various aspects in such a manner that any conclusion on the preference for a specific slope aspect would be questionable.

The conclusions which can be drawn from the pellet group data are limited by the low frequency of occurrence of groups on the transects. Scattered summer distribution of mule deer would not be conducive to large accumulation of pellet groups. The data do indicate certain usage patterns as described above, however, and the major trend supported by field observations is that most of the area's mule deer occupy the mixed brush vegetation type on higher elevations west of Tract C-a during the summer.

For complete tabulated results of large mammal studies and figures showing large mammal seasonal distribution and sample sites, see pages 3-7-483 through 3-7-514 in the Second Annual Report (RBOSP, 1976).

4. Discussion - A discussion concerning the large mammal baseline definition of Tract C-a and the surrounding area based on one year of study must take several facts into consideration. Since large mammals, especially deer, usually move in response to environmental stimuli, the increased human activity associated with preparation of the study area for development (drill rigs, road construction and maintenance, installation of base stations and monitoring devices) which was occurring during the first year's study may have had an effect on large mammal activity in the area. How this may have affected the data gathered during the period cannot be determined due to the lack of information on the large mammal distribution before the initial activity period. Since large mammal distribution, particularly mule deer distribution, depends largely on weather and snow conditions, different levels of use of specific areas are observed during mild winters than are observed during relatively severe winters. Population levels and structure of the entire Piceance herd change in response to many factors, some of which are weather, condition of the range, and managed hunting. The following discussion will attempt to characterize large mammal distribution in, and utilization of, the study area based on what has been learned in the past year.

Mule deer use of the area varies seasonally. The general pattern observed during the 1974-75 sampling season was a gradual influx of deer into the vicinity of Tract C-a during October. Migration movement studies were not conducted during the fall/winter period; however, general observations at that time indicated that animals started to move into and through the study area on and near Tract C-a in mid-October. Deer were observed on Tract C-a throughout the winter, and it can be assumed that deer movements in the area continued through the winter period. Deer were essentially absent from the area west of Tract C-a after January, 1975. This pattern probably occurs during most winters based on information gathered on deer distribution by the Colorado Division of Wildlife (Bartmann, 1972, 1973 and 1974). It is generally assumed

that a decline in temperature and increase in snow fall initiate fall deer migrations (Richens, 1966; Russell, 1932). The time, rate, and extent of migrations vary with environmental conditions (Richens, 1966). Mule deer move in search of suitable food and shelter, and distribution is often influenced by the distribution of these necessities. Suitable food and shelter may be present in an area one winter, due to a light snowfall, while the next year the area may be unsuitable due to deep snows. Snow depths greater than 46 to 51 cm (18 to 20 in) essentially preclude mule deer use of most of the area (Loveless, 1967).

As the winter progressed, the largest concentrations of mule deer were located in the eastern portion of the study area. This area is within the upper elevational boundary of the average winter range line proposed by Baker (1970) for that area of the Piceance Basin. Animals remained in the area east of Tract C-a through the spring. During this period, the deer concentrated in the bottomlands during the early mornings and evenings where they foraged on the new growth. The animals probably bed down in the more rugged country nearby during the day. Mule deer generally concentrate in specific meadows along the Piceance Creek drainage during spring before moving on to summer range, although they do not concentrate consistently each year (Bartmann, 1972). The movement through the study area and back to summer range was monitored during a portion of the spring 1975 migration movement. The information gathered indicates that this movement takes place over an extended period as the deer disperse from their winter range. The deer appeared to meander through the area and gradually drift to higher elevations as individuals and small groups rather than en masse along a well-defined route. This interpretation agrees with interpretations made in several studies of mule deer migratory behavior in the Piceance Basin and elsewhere in the western United States (Bartmann, 1968). It is generally postulated that development of green forage and other environmental factors influence the spring migration movement (Richens, 1966).

Little mule deer activity was evident on Tract C-a during the summer months. Most of the deer in the study area were west of Tract C-a by late May. The

area west of Tract C-a is characterized by mixed brush stands intermingled with sagebrush, pinyon-juniper, and upland meadow vegetation types. This admixture of vegetation seems to be preferred summer range over the more extensive pinyon-juniper vegetation type located on Tract C-a.

Based on the mule deer distribution patterns observed during the 1974-75 study, Tract C-a itself might tentatively be termed transition range and upper winter range. During the mild winter the vicinity of Tract C-a will be used more extensively than during a severe winter. Migrating mule deer utilize Tract C-a which is a small portion of their migratory corridor as they move through toward summer or winter range.

The deer in the Tract C-a study area are part of a larger herd called the Piceance Basin deer herd. This herd produces a large portion of the deer harvested each year in Colorado. Game Management Unit 22, which encompasses the Piceance Creek area, has been listed among the top ten game management units in the state for the highest number of hunters and largest number of deer harvested for several years (Colorado Division of Game, Fish and Parks, 1971, 1972; Colorado Division of Wildlife, 1973, 1974, 1975). Over-winter mortality attributed to severe winters in the early 1970's decreased the population of the Piceance Creek herd. The Colorado Division of Wildlife is presently attempting to manage the population so a large number of deer are available for harvest each year.

The other large mammals observed in the study area include elk and feral horses. Relatively few elk are found in the study area. Scattered elk herds occur west and south of Tract C-a, while no elk have been observed on Tract C-a.

Feral horses utilize portions of the study area throughout the year, and are more frequently observed west of Tract C-a, although herds also occur on both 84 Mesa and Wolf Ridge. The largest herd of horses observed in the study area is frequently located on Landing Strip Ridge. Most of the feral horses observed on Tract C-a have been near the boundaries of the tract, and several

observations have recorded herds just outside the tract boundaries. This distributional pattern may be due to the disturbance factors associated with site preparation.

The feral horses appear to prefer windblown ridges during the winter and to range throughout the entire study area during the remaining parts of the year. Fences restrict their movements over certain portions of the study area.

In summary, feral horses and domestic livestock appear to be the only large herbivores present on Tract C-a during the summer period. Mule deer join them during the fall, winter, and spring; but elk have not been observed on Tract C-a and probably rarely, if ever, use the area within its boundaries.

C. Mammalian Predators

1. Objectives - The purpose of the mammalian predator investigations is to document the presence and relative abundance of large predators (coyotes, bobcats, black bears and mountain lions) and small predators (ringtails, martens, weasels, etc.) within and adjacent to Tract C-a.

2. Methods

a. Data Collection - Two census methods, the scent-station visitation technique and the siren-elicited howling response procedure, are being used to gather information on large predator populations. These methods were selected after a thorough review of the literature and are designed to yield reliable indices of large predator abundance and distribution. In addition, Havahart traps are set to determine the presence of small predators. Refer to pages 3-7-515 through 3-7-518 of the Second Annual Report (RBOSP, 1976) for complete methodology used in mammalian predator sampling.

b. Data Analysis - See pages 3-7-518 through 3-7-519 in the Second Annual Report (RBOSP, 1976) for specific methods used in analyzing mammalian predator data.

3. Data Summary - The mammalian predator scent-station survey was initiated on November 11 through 15, 1974, and repeated during February 10 through 14, 1975, June 22 through 26, 1975 and October 19 through 23, 1975. The siren-elicited howling response method as a coyote survey technique was employed concurrently with the scent-station method on two nights of suitable weather conditions during the sampling period. The specific dates of the siren survey were November 11 and 13, 1974; February 10 and 12, 1975; June 22 and 25, 1975; and October 19, 1975. Only one night of the siren survey was performed during October, 1975 because of unfavorable weather conditions and the onset of mule deer hunting season.

The results of the scent-station survey and the corresponding relative abundance indices for all sampling periods are summarized in Table 3-7-7, and the results of federally surveyed lines within similar habitats with similar physiographic characteristics are presented in Table 3-7-8. Siren elicited howling response results are summarized in Table 3-7-9.

a. Scent-Station Visitation Technique - Results of the scent-station visitation technique indicate that the coyote (*Canis latrans*) and the weasel (*Mustela frenata* or *M. erminea*) are the most abundant mammalian predators in the Tract C-a area. They are the only predators that have responded to this survey technique.

The low level of response (an index of 19 for coyotes and 14 for weasels) in the November, 1974 sample may be attributed to the fact that the sampling period immediately followed the mule-deer hunting season. There are two reasons why such a condition might affect scent-station data: (1) the animals would probably be more wary following a period of increased human activity, especially one which included firearm use; and (2) the animals would be less likely to roam in search of food due to the availability of camp refuse, viscera from hunter kills, and the easy prey afforded by wounded deer (R. Krager, Colorado Division of Wildlife's Little Hills Experimental Station, personal communication, 1974).

Table 3-7-7

SCENT STATION VISITATION TECHNIQUE RESULTS AND RELATIVE ABUNDANCE INDICES AS CALCULATED FROM DATA COLLECTED DURING NOVEMBER, 1974 AND FEBRUARY, JUNE AND OCTOBER, 1975 FOR RBOSP

	Nov. 1974	Feb. 1975	June 1975A	June 1975B	Oct. 1975A	Oct. 1975B
Operable Station Nights	211	166	228	172	187	193
Coyote index	19	78	26	35	37	47
No. of visits	4	13	6	6	7	9
Weasel index	14	12	26	35	27	26
No. of visits	3	2	6	6	5	5

Table 3-7-8

SCENT-STATION VISITATION TECHNIQUE RESULTS AND RELATIVE ABUNDANCE INDICES FROM FEDERALLY-SURVEYED LINES WITHIN GENERALLY SIMILAR HABITATS WITH SIMILAR PHYSIOGRAPHIC CHARACTERISTICS (1973-1975) AS THOSE SAMPLED FOR RBOSP

Colorado

	1973			1974			1975*		
Survey line number	14	17	18	14	17	18	14	17	18
Operable station nights	250	250	250	248	191	239			
Coyote index	148	96	28	48	26	54			
Number of visits	37	24	7	12	5	13			

Utah

	1973			1974			1975*		
Survey line number	14	17	18	14	17	18	14	17	18
Operable station nights	200	199	250	140	192	250			
Coyote index	60	45	20	7	26	164			
Number of visits	12	9	5	1	5	41			

* Data not yet received.

Table 3-7-9

COYOTE SIREN CENSUS RESULTS AND STATION AND GROUP RESPONSE INDICES CALCULATED FROM DATA COLLECTED NOVEMBER, 1974 AND FEBRUARY, JUNE AND OCTOBER, 1975 FOR RBOSP

Number of Stations	Number of Responding Stations	Number of Responding Groups	Station Response Index *	Group Response Index **
		<u>Sample 1 (November, 1974)</u>		
15	10	13	67	87
		<u>Sample 2 (February, 1975)</u>		
11	7	10	64	91
		<u>Sample 3 (June, 1975)</u>		
20	10	20	50	100
		<u>Sample 4 (October, 1975)</u>		
10	4	4	40	40

* Station Response Index = $\frac{\text{Total number of stations with response}}{\text{Total number of stations}} \times 100$

** Group Response Index = $\frac{\text{Total number of groups responding}}{\text{Total number of stations}} \times 100$

Coyote response during February, 1975 increased greatly (an index of 78) over the November sample and remains the highest of all four sampling periods, perhaps because the scarcity of food in the winter encouraged coyotes to roam farther and encounter more stations. Response during June and October, 1975 was moderate for both sampling lines, with indices ranging between 26 and 47 for coyotes and between 26 and 35 for weasels.

The scent-station visitation technique is not designed as a method for determining mammalian predator densities. However, the technique may be applied as an index of relative abundance and, as with all indices, the greater the sample size, the greater the certainty of an accurate index. For this reason, the sampling effort on Tract C-a was increased to two 50-station lines. Although this constitutes 100 scent-stations, the possibility of contagion (one animal visiting more than one station) between stations located only 0.5 km (0.3 mi) apart required that each line be considered as only one sample, thus strict statistical comparison between sampling lines cannot be made. However, a general comparison between the relative abundance indices calculated for the Tract C-a area and those indices calculated for federally surveyed lines within similar habitats with similar physiographic characteristics illustrates the range of variation in data -- both between sampling lines and from year to year -- and shows that the data from Tract C-a fall within this range.

The scent-station visitation technique is presently undergoing research to determine its sensitivity in limited areas and, perhaps with modification, its possible application as a technique that will provide density estimates (Robert Roughton, United States Fish and Wildlife Serivce, personal communication, 1975).

b. Coyote Siren Census - Results of the siren-elicited howling response survey are moderately consistent for most of the samples taken thus far with station-response indices ranging between 87 and 100. The group-response index of 40 for the October, 1975 sample may be low because of the limited sample size during that period. This technique appears to be working satis-

factorily and should prove valuable as an alternate indicator of relative coyote abundance over a period of time. The nature of the results obtained with this method during November, 1974 serve to support the hypothesis that coyote numbers were not reduced as indicated by the scent-station survey, but that the animals were less likely to approach scent-stations immediately following the mule deer hunting season.

June, 1975 was the only sampling period thus far when all 10 siren stations were accessible for two nights. Snow and snow-packed conditions have prohibited complete sampling in all other sampling periods.

c. Other Large Predator Investigations - Records of mammalian predator sightings during large mammal and raptor aerial surveys as well as field observations during the course of other field investigations, are being compiled. Efforts to locate past records of abundance and distribution of mammalian predators, records of damage claims to livestock, hunting kill, and trapping records of predatory mammals specific to the area have been unsuccessful. Many individuals from various federal and state agencies have been contacted in an attempt to acquire this information, but formal records were not available. However, further efforts will hopefully yield this information.

d. Small Predators - The limited qualitative Havahart live-trapping program has yielded two species of small predators, the long-tailed weasel (*Mustela frenata*) and the short-tailed weasel (*M. erminea*).

Observations of these mammalian predators are plotted on field maps and distribution maps summarizing all mammalian predator observations will be presented in a final report covering two years of baseline data accumulation.

Tabulated results of mammalian predator investigations may be referenced in the Second Annual Report (RBOSP, 1976) pages 3-7-523 through 3-7-530.

4. Discussion - Records of tracks, scats, and other definitive signs recorded on and near Tract C-a, as well as the results of the scent-station visitation survey and winter track counts, indicate that the coyote (*Canis latrans*), the long-tailed weasel (*Mustela frenata*), and the short-tailed

weasel (M. erminea) were the most abundant mammalian predators in the Tract C-a area. Coyote relative abundance indices (range 19 to 78) are generally near the midpoint of the range of variation exhibited by federally-surveyed lines (range 7 to 148) within similar habitats with similar physiographic characteristics in Colorado and seem to indicate that coyote populations are about average for the region (see Tables 3-7-7 and 3-7-8).

Other mammalian predators that have been documented in the study area are the bobcat (Lynx rufus) and the badger (Taxidea taxus).

D. Avifauna

1. Objectives - The purpose of the avian census program is to identify the bird species that occur within the study area on a seasonal and annual basis. Density figures are to be derived for dominant species and an objective designation of important species is developed. The importance of an avian species may be determined by demonstrating its recreational or economic value; threatened, rare or endangered status; esthetic value; or critical role in the structure and function of the ecosystem. Favored nesting habitats of important breeding species will be indicated.

2. Methods

a. Data Collection

1) General Avifauna - Population densities of songbirds and certain non-song birds residing in or utilizing major vegetation types on Tract C-a were determined by the strip transect method developed by Emlen (1971). These quantitative censuses commenced in early October 1974 with six surveys (October and December 1974; February, April, June and October 1975) being conducted during the first year of the baseline study. Fifteen habitats were censused for species composition and abundance, with all transects, except the riparian starting at or traversing one of the 14 small mammal live trapping grids.

The strip transect method consisted of walking a 800 m long and 244 m wide strip and recording all birds heard or seen as to species and perpendicular distance to the central transect line. Qualitative transects are conducted during each general bird sampling period in order to determine the presence of bird species that may not be observed during quantitative transects or to inventory bird species and sample habitats not effectively surveyed by strip transect techniques. These surveys consist of walking a route in a given vegetation type approximately 250 m long, and recording all birds encountered, by species and numbers, on a data form.

2) Upland Gamebirds - Sage grouse nesting success during the 1975 breeding season was determined by driving a 32 km brood census road through sagebrush habitat on two consecutive mornings during mid July. All sage grouse encountered on the transect route are flushed and tallied according to sex and age.

Blue grouse numbers and distribution were determined by traversing a 24.2 km route along open conifer and aspen stands and intermixed aspen-shrubs. The route was traveled on two consecutive mornings during May 1975. All grouse seen or heard were recorded as to sex and age.

Density of mourning doves, breeding inhabitants of almost all vegetative communities on Tract C-a and vicinity, is determined from strip transect counts and subsequent calculations.

3) Waterfowl - Waterfowl were censused during October 1974 and April, June and August 1975. During each census period, the Stake Springs Draw impoundment (NW 1/4, Section 14, T2S, R99W) was visited during morning, mid-day, and early evening for a minimum of two days to determine the extent of utilization by migratory or breeding waterfowl. The pond is observed for approximately 15 minutes during each of the three visits. Each bird observed on the pond is identified as to species, and the number of individuals per species is recorded on a standard field data form. In addition to geese and ducks, shorebird use of the pond is also determined.

4) Raptors

a) Aerial Surveys - Raptorial birds include the vultures, hawks, eagles, falcons, and the owls. The common raven is also included in this category, due to its similar ecological role (Craighead and Craighead, 1969). Low-level aerial surveys utilizing a high winged aircraft are being conducted to determine relative abundance and distribution of raptors utilizing or residing in the vicinity of Tract C-a. These flights were initiated in November 1974 and have continued bimonthly through August 1975. The plane is flown along standardized transects at approximately the same air speed and altitude paths.

Raptors seen by the pilot and two observers (positioned on opposite sides of the plane) are located and identified as to species and, when possible, age class and then recorded on a tape recorder. Subsequent to the flight, all information recorded on the tape is transcribed by each observer onto a standard aerial raptor census report and summary form.

b) Ground Surveys - During late April and early June 1975 potential raptor nesting habitats on Tract C-a and the surrounding area were traversed on the ground for four consecutive days. Raptors noted during these and any other avian field activities are recorded as to species, age class (based on criteria developed by Bent, 1961; Peterson, 1947, 1961; and Brown and Amadon, 1968), and location of observation. All raptor nests (active or inactive) encountered are carefully examined and their locations plotted on field maps. Photographs are taken of the nest site area. Nests located during the non-nesting period are revisited and watched for evidences of occupancy; the species occupying each active nest is determined.

During December 1974 and 1975 and April 1975 and 1976, a 48.4 km long, 16.1 km interval marked, standardized road transect is traversed at night to assess owl activity. These surveys commence within two hours after sunset. At each stop, the censuser leaves the vehicle, walks approximately 15 m away, and records on a data sheet, by species, the number of owls heard or observed during a five-minute period. A more complete discussion of methodology used in avifauna studies may be found in the Second Annual Report (RBOSP, 1976), pages 3-7-531 through 3-7-537.

b. Data Analysis

1) Population Density Estimates - Estimations of population density for species observed on strip transects are determined by one of three methods depending on the conspicuousness of the species to the observer. For species that are highly active and conspicuous so that the observer can assume that all individuals of that species within the transect area have been tallied, method "A" is used. Method "A" simply involves division of the total number of individuals seen on the transect by the total area of the transect to obtain

estimates of number per km^2. To determine number per hectare (#/ha), a factor of 0.1 is multiplied by the number of birds observed.

2) Index of Relative Abundance - Once a population density estimate is computed, it is used to determine the percent relative abundance (% RA) for each species. The % RA is defined as follows:

$$\% \ RA = \frac{\text{Density of species A}}{\Sigma \text{ density of all species}} \times 100$$

3) Species Diversity - Shannon-Weiner species diversity indices are calculated for each strip transect during each sampling period.

4) General Data Efficacy - A number of factors may influence the accuracy and utility of data used to calculate population abundances of animals. Certain factors are intrinsic to the field and data analysis methodologies employed. Other factors are determined by circumstances extrinsic to the sampling technique used. Extrinsic factors become especially influential in reducing the confidence one can place in data on density estimates. Because birds are highly mobile and, during the non-breeding season, often exhibit non-uniformity in their distribution patterns, density estimation becomes difficult; thus it is often necessary to qualify the meaning of bird density values derived or to discuss the avian species in terms of relative abundance or numbers observed (numbers observed is only mentioned when few species were observed or when a flock size is discussed). For a more complete discussion of avifauna data analysis methods and formulae, refer to pages 3-7-537 through 3-7-540 of the Second Annual Report (RBOSP, 1976). A more detailed discussion of the factors that influence the accuracy and utility of avifauna data is included on pages 3-7-540 through 3-7-543 of the Second Annual Report (RBOSP, 1976).

5) Importance Values - An importance value was calculated from the population density estimates for each songbird species in each habitat using a modification of methods described by Kricher (1973). Importance values (Table 3-7-10) (IV) were calculated as follows:

Table 3-7-10

IMPORTANCE VALVES* FOR EACH SONGBIRD SPECIES OBSERVED ALONG STRIP TRANSECTS CONDUCTED DURING OCTOBER, 1974 THROUGH OCTOBER, 1975

SPECIES	IMPORTANCE VALUES														
	TRANSECTS														
	13	14	7	12	5	4	10	9	6	11	2	8	3	1	15
	Douglas Fir	Aspen	Upland Meadow	Upland Mixed Brush	Lowland Mixed Brush	Pinyon-Juniper/ Mixed Brush	Pinyon-Juniper/ North Slope	Pinyon-Juniper/ South Slope	Pinyon-Juniper/ Sagebrush	Upland Sagebrush	Lowland Sagebrush	Greasewood-Sagebrush	Rabbitbrush	Bottomland Meadow	Riparian
Mourning Dove								9.5				4.2			2.8
White-throated Swift		3.6			9.6			6.4					4.6		
Broad-tailed Hummingbird		12.5			16.7		6.3		5.8						4.1
Common Flicker		7.2		6.5		7.8	4.6	6.4		16.1		3.9			
Downy Woodpecker	6.8	7.2													
Hammond Flicker	4.5														
Gray Flycatcher							4.6								
Western Wood Pewee														5.9	2.6
Horned Lark			97.2						53.4		36.5			22.0	
Barn Swallow														3.6	
Cliff Swallow								8.5	6.2			3.9	5.8	4.4	3.8
Violet-green Swallow														4.4	
Tree Swallow								6.4	5.4					3.6	
Rough-winged Swallow								6.4				4.2	4.6	6.6	2.6
Steller's Jay	13.4			6.5											
Scrub Jay					9.6	15.5	4.2	27.4	15.2	8.0		7.7	9.9		5.3
Pinyon Jay						7.8		12.7	5.0			4.8	5.8		
Black-billed Magpie						23.4	4.2							12 3	5.3
Clark's Nutcracker	3.6	3.6		6.5			4.2		5.0	8.0		3.9			
Raven	3.3	3.6		6.5				6.4	5.0	8.0		7.7		11.6	2 8
Black-capped Chickadee	16.0	24.1													
Mountain Chickadee	33.7	37.2			13.6	18.4	42.7	7.4	5.4				15.7		4.1
Plain Titmouse							8.8								
Bushtit								17.9	12.5				10.4		
White-breated Nuthatch							4.2								
Red-breasted Nuthatch	33.7						8.8								
Pygmy Nuthatch	6.6														
House Wren	5.0	3.9			10.9					8.0					
Sage Thrasher												4.8			
Robin	9.1				10.9		4.2			8.9				4.4	8.7
Townsend's Solitare		4.7													
Hermit Thrush	8.9														
Mountain Bluebird			10.1	23.4	21.5	33.7	9.4	44.2	21.1	29.5	36.1	16.9	31.9	12.3	14.1
Blue-gray Gnatcatcher					29.4	12.4			9.4						3.8
Ruby-crowned Kinglet	10.8	16.6					8.0								
Water Pipit													7.5	11.6	2.8
Northern Shrike					9.6										
Starling															
Gray Vireo								13.7							2.8
Solitary Vireo							4.6	13.7							
Warbling Vireo		7.7													
Tennessee Warbler		6.2													
Orange-crowned Warbler		7.7													3.3
Yellow-rumped Warbler										36.6		6.0	14.9	3.6	27.6
Black-throated Gray Warbler							8.8	13.7							
MacGillivray's Warbler		6.2		9.6											
Bobolink														5.9	
Western Meadowlark														16.7	2.8
Red-winged Blackbird															
Brewer's Blackbird														19.0	24.8
Brown-headed Cowbird														9.6	2.8
Black-headed Grosbeak		6.2					4.2								

Table 3-7-10 (Continued)

SPECIES	IMPORTANCE VALUES														
	TRANSECT														
	13	14	7	12	5	4	10	9	6	11	2	8	3	1	15
	Douglas fir	Aspen	Upland Meadow	Upland Mixed Brush	Lowland Mixed Brush	Pinyon-Juniper Mixed Brush	Pinyon-Juniper North Slope	Pinyon-Juniper South Slope	Pinyon-Juniper Sagebrush	Upland Sagebrush	Lowland Sagebrush	Greasewood-Sagebrush	Rabbitbrush	Bottomland Meadow	Riparian
Cassin's Finch	4.0														4.6
Black Rosy Finch				11.8											
Brown-capped Rosy Finch				9.2											
Pine Siskin	6.9														
Red Crossbill	[illegible]														
Green-tailed Towhee		4.7	11.1	9.6	13.6	18.4	5.5		7.8	17.8		7.2	7.5		3.6
Rufous-sided Towhee		5.4				13.9			10.6				4.6		
Grasshopper Sparrow							4.6								
Lark Bunting											14.7			5.9	
Vesper Sparrow			16.9	11.4					7.0	33.9	16.5	11.0		8.8	
Lark Sparrow									7.8		25.4	4.2			
Sage Sparrow									7.4		47.2				
Dark-eyed Junco	5.0	5.4		23.1	35.9	30.7	17.7					25.6	7.5		12.1
Gray-headed Junco	21.0	26.1		53.0	18.8		5.5					22.1	10.8		[illegible]
Tree Sparrow												6.0		4.4	
Chipping Sparrow							29.9					11.0			
Brewer's Sparrow			16.9	10.6		18.4	4.2		10.9	25.9	23.6	25.3	19.4	8.8	[illegible]
White-crowned Sparrow			16.9									8.9	31.8	8.8	8.6
Golden-crowned Sparrow													7.5		
Fox Sparrow															3.0
Song Sparrow												12.2		8.8	16.6
[illegible]			[illegible]												
Snow Bunting				13.1											
TOTALS	199.6	199.8	199.1	200.8	199.6	200.4	199.2	200.7	200.9	200.7	200.0	201.5	200.2	203.0	200.1

* Importance value for each habitat =

$$\frac{\text{\# ha of species A over all seasons}}{\text{total \# ha of all species over all seasons}} \times 100 + \frac{\text{\# of encounters of species A over all seasons}}{\text{total \# of encounters of all species over all seasons}} \times 100$$

** December, 1974 census is not included due to partial sampling of the 15 transects caused by adverse weather conditions.

$$\text{Importance value for each habitat} = \frac{\text{\#/ha of species A over all seasons}}{\text{total \#/ha of all species over all seasons}} \times 100\% + \frac{\text{\# of encounters of species A over all seasons}}{\text{total \# of encounters of all species over all seasons}} \times 100\%$$

3. Data Summary - Figures presented in this section are not absolute. See The Second Annual Report (RBOSP, 1976) for the ranges of these figures.

a. General Avifauna - This section summarizes information derived from strip transect censuses at 15 locations during the first year of terrestrial investigations. Emphasis of the discussion focuses on species composition, species diversity, population densities, the equitability of distribution among species, and the seasonal status of "important" species within a habitat. The species diversity and equitability of an avian population is discussed qualitatively within this section.

The status, occurrence, and preferred habitats of the 129 species which have been observed in the study area during the first year's investigations are listed in Table 3-7-11. Definitions of terms used to describe status and occurrence are presented in footnotes to this table.

Species population densities (estimated absolute or relative densities) are presented for those species considered to be the most "important" in each habitat; except in those instances where flock size is mentioned or one species was observed, in which case number of individuals encountered is discussed in lieu of population densities. Pertinent information such as preferred habitats, nesting sites, food habits, distribution, and flocking behavior were also mentioned for the "important" species, when literature on these topics was available. The assignment of "biological importance" to bird species is not clear cut. In general, knowledge of the ecological roles played by individual bird species is too sketchy to permit such an assignment, particularly for the many species of songbirds in the study area. In their case, we may operationally consider that the relative abundance and frequency of occurrence of a species provide an index to its biological importance. Thus, any summation of the relative abundance and the relative frequency of a particular species provides

Table 3-7-11

OCCURRENCE, ANTICIPATED STATUS, AND HABITATS AT TIME OF OBSERVATION FOR BIRD SPECIES SEEN BETWEEN OCTOBER 1974 AND OCTOBER 1975*

ORDER FAMILY (Species) Common Name	Occurrence**				Status**					Habitat at Time of Observation***														
	Resident	Summer	Winter	Migrant	Common	Uncommon	Rare	Accidental	Uncertain	Aspen	Douglas fir	Upland Meadow	Mixed Brush (low elevation)	Mixed Brush (high elevation)	Pinyon-juniper (north slope)	Pinyon-juniper (south slope)	Pinyon-juniper/ Mixed Brush	Pinyon-juniper/ Sagebrush	Sagebrush (low elevation)	Sagebrush (high elevation)	Greasewood/ Sagebrush	Rabbitbrush	Riparian	Bottomland Meadow
CICONIFORMES																								
ARDEIDAE																								
(Ardea herodias)																								
Great blue heron				X			X																X	
COCONIIDAE																								
(Plegadis chihi)																								
White-faced ibis				X			X																X	
ANSERIFORMES																								
ANATIDAE																								
(Anas platyrhynatos)																								
Mallard	X				X																		X	
(Anas strepera)																								
Gadwall		X				X																	X	
(Anas crecca)																								
Green-winged teal		X				X																	X	
(Anas discors)																								
Blue-winged teal		X				X																	X	
(Anas cyanoptera)																								
Cinnamon teal		X				X																	X	
(Aythya americana)																								
Redhead		X							X														X	
FALCONIFORMES																								
CATHARTIDAE																								
(Cathartes aura)																								
Turkey vulture		X					X								X	X								
ACCIPITRIDAE																								
(Accipiter gentilis)																								
Goshawk		X							X	X														
(Accipiter striatus)																								
Sharp-shinned hawk		X							X					X										
(Accipiter cooperii)																								
Cooper's hawk		X				X								X	X	X	X	X						
(Buteo jamaicensis)																								
Red-tailed hawk	X				X									X	X		X	X	X				X	X
(Buteo swainsoni)																								
Swainson's hawk				X					X															X
(Buteo lagopus)																								
Rough-legged hawk			X		X							X	X						X	X			X	X
(Aquila chrysaetos)																								
Golden eagle	X				X							X					X	X	X	X			X	X
(Haliaeetus leuocephalus)																								
Bald eagle			X				X																X	X
(Circus cyaneus)																								
Marsh hawk	X				X							X												X
FALCONIDAE																								
(Falco mexicanus)																								
Prairie falcon	X						X					X				X			X					X
(Falco peregrinus)																								
Peregrine falcon		X		X			X								X	X								
(Falco columbarius)																								
Merlin				X			X					X												
(Falco sparverius)																								
American kestrel	X				X										X	X	X	X	X	X	X	X	X	X
GALLIFORMES																								
TETRAONIDAE																								
(Dendragapus obscurus)																								
Blue grouse	X				X					X	X			X										
(Centrocercus urophasianus)																								
Sage grouse	X				X									X					X	X				
GRUIFORMES																								
GRUIDAE																								
(Grus canadensis tabida)																								
Greater sandhill crane				X					X										X					

Table 3-7-11 (Continued)

ORDER FAMILY (Species) Common Name	Occurrence				Status					Habitat at Time of Observation														
	Resident	Summer	Winter	Migrant	Common	Uncommon	Rare	Accidental	Uncertain	Aspen	Douglas fir	Upland Meadow	Mixed Brush (low elevation)	Mixed Brush (high elevation)	Pinyon-juniper (north slope)	Pinyon-juniper (south slope)	Pinyon-juniper/ Mixed Brush	Pinyon-juniper/ Sagebrush	Sagebrush (low elevation)	Sagebrush (high elevation)	Greasewood/ Sagebrush	Rabbitbrush	Riparian	Bottomland Meadow
GRIUFORMES																								
RALLIDAE																								
(Rallus limicola)																								
Virginia rail		X					X																X	
(Porzana carolina)																								
Sora		X					X																X	
CHARADRIIFORMES																								
CHARADRIIDAE																								
(Charadrius semipalmatus)																								
Semipalmated plover				X			X							X										
(Charadrius vociferus)																								
Killdeer		X			X																		X	
SCOLOPACIDAE																								
(Capella gallinago)																								
Common snipe		X				X																	X	
(Actitis macularia)																								
Spotted sandpiper		X				X																	X	
(Tringa solitoria)																								
Solitary sandpiper		X				X																	X	
(Tringa flavipes)																								
Lesser yellowlegs				X			X																X	
(Numenius americanus)																								
Long-billed curlew				X			X																X	
RECURVIROSTRIDAE																								
(Recurvirostra americana)																								
American avocet		X				X																	X	
PHALAROPOIDAE																								
(Steganopus tricolor)																								
Wilson's phalarope		X				X																	X	
COLUMBIFORMES																								
COLUMBIDAE																								
(Zenaida macroura)																								
Mourning dove		X			X										X	X			X		X		X	X
STRIGIFORMES																								
STRIGIDAE																								
(Otus asio)																								
Screech owl	X								X															
(Bubo virginianus)																								
Great horned owl	X				X						X				X	X								X
(Glaucidium gnoma)																								
Pygmy owl			X						X		X													
(Asio flammeus)																								
Short-eared owl			X						X															X
CAPRIMULGIFORMES																								
CAPRIMULGIDAE																								
(Phalaenoptilus nuttallii)																								
Poor-will		X			X								X	X					X	X	X	X		
(Chordeiles minor)																								
Common night hawk		X			X										X	X	X	X						X
APODIFORMES																								
APODIDAE																								
(Aeronautes saxatalis)																								
White-throated swift		X			X					X		X		X		X						X		
TROCHILIDAE																								
(Selasphorus platycercus)																								
Broad-tailed hummingbird		X			X					X					X			X						
PICIFORMES																								
PICIDAE																								
(Colaptes auratus)																								
Common flicker	X				X					X					X	X	X	X						
(Dendrocopos pubescens)																								
Downy woodpecker	X					X				X	X													

Table 3-7-11 (Continued)

ORDER / FAMILY / (Species) / Common Name	Occurrence: Resident	Summer	Winter	Migrant	Status: Common	Uncommon	Rare	Accidental	Uncertain	Habitat at Time of Observation: Aspen	Douglas fir	Upland Meadow	Mixed Brush (low elevation)	Mixed Brush (high elevation)	Pinyon-Juniper (north slope)	Pinyon-Juniper (south slope)	Pinyon-Juniper/ Mixed Brush	Pinyon-Juniper/ Sagebrush	Sagebrush (low elevation)	Sagebrush (high elevation)	Greasewood/ Sagebrush	Rabbitbrush	Riparian	Bottomland Meadow
PASSERIFORMES																								
TYRANNIDAE																								
(Sayornis saya)																								
Say's phoebe		X			X																X	X		X
(Empidonax hammondii)																								
Hammond's flycatcher		X							X		X													
(Empidonax wrightii)																								
Gray flycatcher		X				X									X				X					
(Contopus sordidulus)																								
Western wood pewee				X		X												X	X		X	X	X	X
ALAUDIDAE																								
(Eremophila alpestris)																								
Horned lark	X				X							X							X	X				X
HIRUNSINIDAE																								
(Tachycineta thalassina)																								
Violet-green swallow		X			X							X			X								X	X
(Iridoprocne bicolor)																								
Tree swallow		X				X									X	X		X						X
(Stelgidopteryx ruficollis)																								
Rough-winged swallow		X				X																	X	X
(Hirundo rustica)																								
Barn swallow		X				X																	X	X
(Petrochelidon pyrrhonota)																								
Cliff swallow		X			X																		X	
CORVIDAE																								
(Cyanocitta stelleri)																								
Steller's Jay	X				X						X													
(Aphelocoma coerulescens)																								
Scrub Jay	X				X								X			X	X	X	X	X	X	X		
(Pica pica)																								
Black-billed magpie	X				X							X	X						X		X	X	X	
(Corvus corax)																								
Common raven	X				X							X	X	X	X	X	X	X	X	X	X	X	X	X
(Corvus brachyrhynchos)																								
Common Crow				X					X															X
(Gymnorhinus cyanocephalus)																								
Pinyon Jay	X				X										X	X	X	X						
(Nucifraga columbiana)																								
Clark's nutcracker	X				X					X	X					X	X	X	X					
PARIDAE																								
(Parus atricapillus)																								
Black-capped chickadee	X				X					X	X													
(Parus gambeli)																								
Mountain chickadee	X				X					X	X				X	X								
(Parus inornatus)																								
Plain titmouse	X				X										X	X								
(Psaltriparus minimus)																								
Bushtit	X					X											X	X				X		X
SITTIDAE																								
(Sitta carolinensis)																								
White-breasted nuthatch	X					X									X									
(Sitta canadensis)																								
Red-breasted nuthatch	X				X						X				X									
(Sitta pygmaea)																								
Pygmy nuthatch			X				X					X												
CERTHIIDAE																								
(Certhia familiaris)																								
Brown Creeper				X			X								X									

Table 3-7-11 (Continued)

ORDER FAMILY (Species) Common Name	Occurrence: Resident	Occurrence: Summer	Occurrence: Winter	Occurrence: Migrant	Status: Common	Status: Uncommon	Status: Rare	Status: Accidental	Status: Uncertain	Habitat at Time of Observation: Aspen	Douglas Fir	Upland Meadow	Mixed Brush (low elevation)	Mixed Brush (high elevation)	Pinyon-juniper/ (north slope)	Pinyon-juniper/ (south slope)	Pinyon-juniper/ Mixed Brush	Pinyon-juniper/ Sagebrush	Sagebrush (low elevation)	Sagebrush (high elevation)	Greasewood/ Sagebrush	Rabbitbrush	Riparian	Bottomland Meadow
PASSERIFORMES																								
TROGLODYTIDAE																								
(*Troglodytes aedon*)																								
House wren		X			X					X	X		X	X	X				X					
(*Salpinctes obsoletus*)																								
Rock wren		X				X													X		X	X		
MIMIDAE																								
(*Oreoscoptes montanus*)																								
Sage thrasher		X				X															X			
TURDIDAE																								
(*Turdus migratorius*)																								
American robin		X			X						X		X		X				X		X	X		X
(*Catharus guttata*)																								
Hermit thrush		X				X					X				X									
(*Sialia currocoides*)																								
Mountain bluebird		X			X							X	X	X	X	X	X	X	X	X	X	X	X	X
(*Myadestes townsendii*)																								
Townsend's solitaire			X			X				X														
SYLVIIDAE																								
(*Polioptila caerulea*)																								
Blue-gray gnatcatcher		X			X								X				X	X	X		X	X	X	
(*Regulus calendula*)																								
Ruby-crowned kinglet	X					X				X	X													
MOTACILLIDAE																								
(*Anthus spinoletta*)																								
Water pipit		X					X																X	X
BOMBYCILLIDAE																								
(*Bombycilla cedrorum*)																								
Cedar waxwing				X				X				X												
LANIIDAE																								
(*Lanius excubitor*)																								
Northern shrike			X			X													X		X	X	X	X
(*Lanius ludovicianus*)																								
Loggerhead shrike				X				X																X
STURNIDAE																								
(*Sturnus vulgaris*)																								
Starling				X	X																		X	X
VIREONIDAE																								
(*Vireo vicinior*)																								
Gray vireo		X				X										X								
(*Vireo solitarius*)																								
Solitary vireo		X				X									X	X								
(*Vireo olivaceus*)																								
Red-eyed vireo		X						X		X														
(*Vireo gilvus*)																								
Warbling vireo		X			X					X														
PARULIDAE																								
(*Vermivora peregrina*)																								
Tennessee warbler		X						X		X														
(*Vermivora celata*)																								
Orange-crowned warbler		X				X				X														
(*Vermivora virginiae*)																								
Virginia's warbler				X			X																X	
(*Dendroica petechia*)																								
Yellow warbler		X					X								X								X	
(*Dendroica coronata*)																								
Yellow-rumped warbler		X			X														X		X	X	X	X
(*Dendroica nigrescens*)																								
Black-throated gray warbler		X			X										X	X								
(*Oporornis tolmiei*)																								
MacGillivray's warbler		X			X					X				X										
PLOCEIDAE																								
(*Passer domesticus*)																								
House sparrow	X								X															

Table 3-7-11 (Continued)

ORDER FAMILY (Species) Common Name	Occurrence				Status					Habitat at Time of Observation														
	Resident	Summer	Winter	Migrant	Common	Uncommon	Rare	Accidental	Uncertain	Aspen	Douglas Fir	Upland Meadow	Mixed Brush (low elevation)	Mixed Brush (high elevation)	Pinyon-juniper (north slope)	Pinyon-juniper (south slope)	Pinyon-juniper/ Mixed Brush	Pinyon-juniper/ Sagebrush	Sagebrush (low elevation)	Sagebrush (high elevation)	Greasewood/ Sagebrush	Rabbitbrush	Riparian	Bottomland Meadow
PASSERIFORMES																								
ICTERIDAE																								
(Dolichonyx oryzivorus)																								
Bobolink		x					x																	x
(Sturnella neglecta)																								
Western meadowlark		x			x																		x	x
(Angelaius phoeniceus)																								
Red-winged blackbird		x			x																		x	x
(Euphagus cyanocephalus)																								
Brewer's blackbird		x			x																		x	x
(Molothrus ater)																								
Brown-headed cowbird		x					x								x									
THRAUPIDAE																								
(Piranga ludoviciana)																								
Western tanager		x					x						x											
FRINGILLIDAE																								
(Pheucticus melanochephalus)																								
Black-headed grosbeak		x					x			x														
(Carpodacus cassinii)																								
Cassin's finch		x					x				x	x											x	
(Carpodacus mexicanus)																								
House finch	x								x															x
(Leucosticte astrata)																								
Black-rosy finch			x			x							x								x			
(Leucosticte australia)																								
Brown-capped rosy finch			x			x							x								x			
(Spinus pinus)																								
Pine siskin		x				x					x												x	
(Loxia curvirostra)																								
Red crossbill		x				x					x													
(Chlorura chlorura)																								
Green-tailed towhee		x			x								x				x	x	x		x	x	x	
(Pipilo erythrodphthalmus)																								
Rufous-sided towhee		x				x				x							x	x				x		
(Calamospiza melanocorys)																								
Lark bunting		x					x													x				x
(Ammordramus savannarum)																								
Grasshopper sparrow		x						x							x									
(Pooecetes gramineus)																								
Vesper sparrow		x			x							x	x					x	x		x			x
(Chondestes grammacus)																								
Lark sparrow		x				x												x	x		x			
(Amphispiza belli)																								
Sage sparrow		x				x												x	x	x				
(Junco hyemalis)																								
Dark-eyed junco			x	x	x					x	x		x	x	x		x				x	x	x	
(Junco canicepts)																								
Gray-headed junco	x				x					x	x		x	x	x						x	x	x	
(Spizella arborea)																								
Tree sparrow			x			x															x	x		x
(Spizella passerina)																								
Chipping sparrow		x			x										x	x					x			
(Spizella breweri)																								
Brewer's sparrow		x			x							x	x	x	x		x	x	x	x	x	x	x	x
(Zonotrichia leucophrys)																								
White-crowned sparrow		x			x							x									x	x	x	x
(Zonotrichia atricapilla)																								
Golden-crowned sparrow				x					x													x		

Table 3-7-11 (Continued)

ORDER FAMILY (Species) Common Name	Occurrence				Status					Habitat at Time of Observation														
	Resident	Summer	Winter	Migrant	Common	Uncommon	Rare	Accidental	Uncertain	Aspen	Doulas-fir	Upland Meadow	Mixed Brush (low elevation)	Mixed Brush (high elevation)	Pinyon-juniper (north slope)	Pinyon-juniper (south slope)	Pinyon-juniper/ Mixed Brush	Pinyon-juniper/ Sagebrush	Sagebrush (low elevation)	Sagebrush (high elevation)	Greasewood/ Sagebrush	Rabbitbrush	Riparian	Bottomland Meadow
PASSERIFORMES																								
FRINGILLIDAE																								
(*Passerella iliaca*)																								
Fox sparrow				x			x																x	
(*Melospiza melodia*)																								
Song sparrow		x			x								x						x		x	x	x	x
(*Calcarius mccownii*)																								
McCown's longspur			x					x				x												
(*Calcarius ornatus*)																								
Chestnut-collared longspur		x						x				x												
(*Plectrophenox nivalis*)																								
Snow Bunting			x					x						x										

* The following authorities are used for bird nomenclature:

American Ornithologists' Union, 1957. Checklist of North American Birds, Fifth edition. Port City Press, Baltimore, Maryland. 691 pages.

American Ornithologists' Union, 1973. Thirty-second supplement to the American Ornithologists'Union checklist of North American Birds (Fifth edition, 1957). Auk 90:411-419.

** Definitions of terms used to describe the status and occurrence of species listed in this table:

Occurrence (based on observations during first year, and supplemented where necessary by literature accounts).

Resident:	A species present during all seasons.
Summer Resident:	A species present throughout the summer and assumed to nest in the region.
Winter Resident:	A species present during winter only.
Migrant:	A species stopping temporarily in the study area during its northward migration in the spring and its southward migration in the fall.

Status (based on observations during first year).

Common:	A species noted regularly in its normal habitat at the proper season of the year.
Uncommon:	A species of regular occurrence in small numbers, at the proper season of the year, but not likely to be observed on every census.
Rare:	A species present in small numbers, and noted only seldomly in proper habitat.
Accidental:	A species which is a casual visitor, and outside its normal range.
Uncertain:	A species whose status needs confirmation.

*** All habitats in which a species has been sighted during quantitative and qualitative censuses are marked for each species. As more sightings are made for wide-ranging species and for species which have generalized habitat responses, additional habitats can be checked.

During the two fall censuses, six different species were recorded on transects in the aspen vegetation type. Thirteen individuals, representing four species, were recorded during October, 1974; and 11 individuals, representing four species, were recorded during October, 1975. The gray-headed junco (44.0% and 65.3%) and mountain chickadee (44.0% and 16.3%) were the most abundant species present during both fall sampling periods. This junco has only been recorded in small flocks in the aspen type during the migratory seasons, when it associated with black-capped chickadees, mountain chickadees, and dark-eyed juncos during spring (flock size of 32), and with the two chickadee species during fall (flock size of 12 in October, 1974 and 8 in October, 1975).

Although only black-capped chickadees have been observed along the aspen transect throughout the year, it is probable that adult mountain chickadees also are permanent residents.

In addition to the two chickadee species, broad-tailed hummingbirds (2.5 birds/ha) and ruby-crowned kinglets (2.5 birds/ha) are characteristic nesting species in this vegetation type. Ruby-crowned kinglets nest throughout the sub-alpine zone in Colorado, usually placing their nests in evergreens. The broad-tailed hummingbird arrives in the region during the first weeks of May and remains into September. Downy woodpeckers (0.1 birds/ha) and common flickers (0.1 birds/ha) also nested in the aspen type in low numbers.

During the breeding season, the aspen transect supported 16 species that were fairly equitably distributed compared with other transects surveyed. A decline in species diversity occurred during the migratory periods. During autumn, this was partially due to the high outflow of breeding species and the low influx of wintering species in the study area. Transient occurrences of migrant flocks prevents meaningful interpretation and comparisons of migration period diversity indices. During winter, the aspen type supported few species. Because of an overwhelming preponderance of individuals belonging to a single species, equitability was very low. See Tables 3-7-246 through 3-7-251 in Second Annual Report (RBOSP, 1976) for species diversity and equitability indices.

an "importance value" for that species. Such a value could approach a maximum only if the species were frequently encountered and in large numbers at each encounter. However, an intermediate value could be obtained either upon encountering one individual of the species on most transects or upon encountering a large number of individuals of that species on only a few transects. The importance values calculated for each songbird species observed along strip transects during the first year's investigations are listed in Table 3-7-10.

Those species distributed in the top range of values from Table 3-7-10 are emphasized in this discussion. Although importance values are obtained from the best site-specific data available, they should be regarded as somewhat tentative due to the small sample sizes from which importance values were derived.

Other species attaining a lesser importance value are also addressed in events where it is necessary to clarify data according to the discussion of Confidence Level of Data given earlier. Although some species mentioned below occur in more than one of the censused vegetation types, their ecological requirements are discussed only once.

1) Aspen (Transect #14) - From October, 1974 through October, 1975, the aspen transect (north slope/8,100 ft) was surveyed five times during four seasons. The aspen transect could not be censused during December, 1974 because of adverse weather conditions. Twenty-one species were recorded in the aspen vegetation type over all sampling periods. On an annual basis, mountain chickadees and gray-headed juncos were the most abundant species recorded. (The mountain chickadee nested in this habitat; the gray-headed junco was the principal species observed during spring and fall migration periods).

2) Douglas fir (Transect #13) - From October, 1974 through October, 1975, the Douglas fir (northern slope/8,100 ft) strip transect was surveyed five times during four different seasons. The Douglas fir transect could not be censused during December, 1974, because of inclement weather. One hundred sixty-six birds, representing 18 species, were recorded. The mountain chickadee and red-breasted nuthatch tended to be the most abundant resident species.

During the two fall sampling periods, 34 individuals of ten different species were recorded in this vegetation type. Twenty-one individuals, representing five species, were recorded during October, 1974, while 13 individuals, representing seven species were recorded during October, 1975. The October species composition exhibited considerable variation from year to year, yet total community densities were similar (3.7 birds/ha and 3.4 birds/ha, respectively). The downy woodpecker and gray-headed junco were the only species encountered during both October sampling periods. Most birds tallied in the fall censuses were species which either had nested in this vegetation type but had not departed by the time of the census or were migrants. The most abundant species encountered during the October, 1974 sampling period were the gray-headed junco (55.2%), dark-eyed junco (22.1%) and ruby-crowned kinglet (19.9%). Percent relative abundance values for the gray-headed junco were similar for both fall censuses (55.2% and 48.6%). The robin and gray-headed junco contributed 74.9% of the relative avian abundance within the Douglas fir transect during October, 1975. The high density (0.8 birds/ha) and percent relative abundance (24.3%) calculated for the robin is considered an overestimate caused by extrapolation from a single sighting close to the central transect site. Nonetheless, this species is expected to occasionally appear in abundance in this vegetative type during migration periods. The robin is an ubiquitous species, occurring in most vegetation types within the study area during the breeding season, including Douglas fir. It has not been observed during the winter, but stragglers from the north are known to winter in Colorado (Bailey and Niedrach, 1965).

Large intermixed flocks of black-capped chickadees (16.9%), mountain chickadees (36.3%), red-breasted nuthatches (36.3%), and pygmy nuthatches (8.7%) were observed in the Douglas fir vegetation type during February. This transect supported the densest population of any of the transects sampled during February (17.0 birds/ha). The disparity between the high density of birds on this

transect and the low population density in the closely associated aspen stands (0.9 birds/ha) is probably attributable to clumped distributions of winter flocks at the time of sampling.

The mountain chickadee (52.2%) and black-capped chickadee (26.1%) continued to be dominating species during the April, 1975 sampling period. By April, winter flocks had dissolved and birds of species which ultimately nested in the area were more evenly distributed throughout the coniferous vegetation type. Mountain chickadee and red-breasted nuthatch densities appeared to decline considerably between February and April (from 6.2 birds/ha to 2.5 birds/ha and 0.8 birds/ha respectively). These changes were probably a consequence of winter flock dispersal to surrounding habitats with the advent of territorial establishment rather than of an actual decline in regional populations.

The Douglas fir stand exhibited the highest species diversity index of any transect for June, 1975. This high diversity was attributed to a large number of species (12) which were present in almost equal numbers (See Table 3-7-250 in Second Annual Report, RBOSP, 1976, for species diversity and equitability indices). No single species was dominant during the breeding season. Red crossbills (1.8 birds/ha), pine siskins (1.6 birds/ha), red-breasted nuthatches (1.6 birds/ha), and mountain chickadees (1.6 birds/ha), however, were more numerous than the other species during June, but Steller's jays (1.2 birds/ha), ruby-crowned kinglets (1.2 birds/ha), and gray-headed juncos (1.2 birds/ha) also attained relatively high densities. The red-breasted nuthatch is the only species that was recorded year-round in the Douglas fir vegetation type. This species' preferred habitat is the evergreen/aspen association ranging from the transition zone to timberline. Although red-breasted nuthatches are migratory their movements are not predictable.

The species diversity indices for the Douglas fir type were relatively high during all seasons; the migratory periods exhibited the lowest comparative values.

3) <u>Upland Meadow (Transect #7)</u> - Fifty-two birds, representing seven species, were recorded in the upland meadow vegetation type during five sampling periods. The horned lark was the most abundant species on an annual basis.

During the two fall sampling periods, three different species were observed in the upland meadow type. Horned larks (40%), white-crowned sparrows (40%), and chestnut-collared longspurs (20%) were recorded during October, 1974. A flock of 23 horned larks was observed during October, 1975. Species diversity was zero for this latter census because this was the only species recorded.

The horned lark was the only species that was consistently observed at this transect during spring, summer, and fall. During winter qualitative surveys, large flocks of this species were noted within the upland meadow vegetation type, but no individuals were tallied on the February census. This species flocks in large groups during winter months, moving from one feeding area to another. Consequently, it might appear only sporadically within this transect strip through the winter. Of the seven species encountered at this plot, the horned lark is the only species expected to be present from time to time during winter.

The chestnut-collared longspur was recorded in the upland meadow type during June, 1975 and in October, 1974. The presence of two individuals during June suggests a possible breeding pair.

Although no birds were noted in upland meadow during the winter strip transect surveys, the horned lark, black-billed magpie, and common raven were recorded in this vegetation type during February qualitative surveys. Harsh windswept conditions usually prevail at Piceance Basin upland meadow sites during winter months (Ward, Slauson and Dix, 1974); these conditions undoubtedly contribute to the paucity of birds recorded during fall and winter surveys.

The horned lark was the only species observed in this vegetative type during the spring sampling period, when it was recorded in low numbers (0.2 birds/ha). The species diversity index for the breeding population in the upland meadow type was about average for all the transects. Six species were recorded during June; the horned lark was observed most frequently (9 individuals; 0.5 birds/ha), but due to differences in detectability, the vesper sparrow (0.8 birds/ha), chestnut-collared longspur (0.8 birds/ha), and Brewer's sparrow (0.8 birds/ha) achieved highest breeding densities. The vesper sparrow and Brewer's sparrow are among the most common summer residents in the study area.

Comparisons of the number of breeding species between upland meadow vegetation type and the adjacent Douglas fir and aspen vegetation types demonstrate upland meadows support the fewest breeding species. This situation probably exists because forests have varied understories and multiple strata of foliage not found in grasslands or meadows. The spatial heterogeneity characteristic of woodlands increases species diversity by increasing the number of different resources available (Pianka, 1971).

4) Mixed Brush (Transect #5) - The mixed brush strip transect was surveyed six times during four different seasons, from October, 1974 through October, 1975. Fifty-five birds, representing 14 species, were recorded over all sampling periods. No one species was observed within this transect during more than one sampling period. Twenty-three individuals, representing six species, were recorded along the northern slope (elevation 7,200 ft) mixed brush transect surveyed during the two fall sampling periods. Mountain chickadees (33.3%) and gray-headed juncos (66.7%) were observed during October, 1974, and scrub jays (3.0%), robins (6.1%), mountain bluebirds (30.3%), and dark-eyed juncos (60.6%) were recorded during October, 1975.

The mountain bluebird, one of the most common summer residents within the study area, was observed in flocks of 8 to 20 along this transect during the fall.

Winter species composition varied. During December the black-billed magpie was predominant (90%), but during the February censuses only a single northern shrike was recorded. The black-billed magpie is a resident throughout Colorado, occurring from the eastern grasslands to elevations of 8,000 ft. It nests in all types of woody plants including serviceberry, cottonwoods, junipers, and pinyons (Bailey and Niedrach, 1965). During winter months, magpies are common scavengers in the tract vicinity, and they are frequently observed feeding on dead animals. Its abundance during December 1974 was probably a response to carrion from the hunting season. The northern shrike is a common winter visitor to western slope valleys (Davis, 1969). Microtines appear to be their most frequent prey (Bent, 1965). According to strip transect and qualitative survey data, it is a regular winter resident of valleys in the study area, yet is present only in small numbers. Larger concentrations have been observed outside the study area along Piceance Creek (Woodward-Envicon, Incorporated, 1974; Woodward-Clyde, Consultants, 1975a, 1975b, 1975c).

Low species diversity indices were computed for the winter sampling periods in the mixed brush vegetation type. Only those birds that range over large areas during winter and have scavenging habits, such as the black-billed magpie and raven, were apparently able to utilize this area efficiently during the winter months.

No birds were observed along this transect during the spring census period, but five breeding species, the white-throated swift (0.1 birds/ha), broad-tailed hummingbird (0.6 birds/ha), house wren (0.2 birds/ha), blue-gray gnatcatcher (1.6 birds/ha), and green-tailed towhee (0.4 birds/ha), were recorded in low numbers during June.

5) Mixed Brush (Transect #12) - The strip transect at this location was surveyed five times during four different seasons. The transect was not censused during December, 1974 because of adverse weather conditions. One hundred fifty-six birds, representing 14 species, were recorded on this southern

slope (elevation 8,300 ft) mixed brush transect. The gray-headed junco and the mountain bluebird were the most abundant species and were the only species recorded during more than one sampling period.

During the two fall sampling periods, four species were recorded in the southern slope mixed brush type. A large (60) mixed flock of dark-eyed juncos and gray-headed juncos was observed during October, 1974; a flock of seven mountain bluebirds and two Clark's nutcrackers were recorded during October, 1975. The October, 1975 species diversity index for this transect was considerably lower than the index for northern slope mixed brush. The indices for both transects during October, 1974, however, were equivalent. As indicated earlier, the transient utilization of habitats by fall and winter birds makes comparisons of diversity and abundances of limited value. It is a matter of chance whether the censuses will encounter a mixed flock within a transect during migration or winter. If one is encountered, a high species diversity index will result; if the transect has few or no birds, the more likely situation, a low diversity will result.

During February, a flock of 13 black rosy finches and seven brown-capped rosy finches and a separate flock of 32 snow buntings were noted on this transect.

The snow bunting is an uncommon visitor to Colorado's eastern slope and has not previously been recorded in western Colorado (Bailey and Niedrach, 1965; Davis, 1969). The sighting is possibly the first record of the species in northwestern Colorado.

Two mountain bluebirds and a flock of 10 gray-headed juncos were the only birds present during April. Twenty-three birds, representing seven species, were recorded during the June sampling period. Approximately 97% of the estimated relative abundance within this transect consisted of Brewer's sparrows (2.1 birds/ha), vesper sparrows (2.5 birds/ha), green-tailed towhees (1.6 birds/ha), and MacGillivray's warblers (1.6 birds/ha). A few Steller's jays (0.1 birds/ha) and common flickers (0.1 birds/ha) were also recorded. The Steller's jay is a common resident of conifers in the Transition Zone and probably nests

within Douglas fir stands near the mixed brush transect. The common flicker is found in a variety of habitats throughout the study area.

Breeding species diversity and population densities were slightly higher for the southern slope mixed brush than for the northern slope mixed brush type (See Table 3-7-250 in Second Annual Report, RBOSP, 1976, for species diversity and equitability indices). The difference in the structural appearance and microenvironments of both variants of the mixed brush type may contribute somewhat to differences in bird occupancy. The number of strata comprising a vegetative community is normally an important determinant of bird species diversity (Bond, 1957). Although the southern slope mixed brush stand does not support as many plant species as does the northern slope stand, its shrubs are larger and therefore may provide more microhabitats for bird utilization. Considerable microenvironmental variation also exists between the two transects due to differences in slope aspect and elevation. Odum (1959) reported variations in species composition and distribution due to microenvironmental differences between north slope and south slope variants of a single vegetation type.

6) <u>Pinyon-Juniper (Transect #10)</u> - From October, 1974 through October, 1975, the pinyon-juniper strip transect was surveyed six times during four different seasons. Eighty-two birds, representing 22 species, were observed within this stand (northern slope/6,900 ft). The mountain chickadee was the most abundant year-round species, and the chipping sparrow was the most common breeding species.

Three species, the black-billed magpie (2.3%), mountain chickadee (54.3%), and ruby-crowned kinglet (43.4%), were present in small numbers during October, 1974. A greater number of species was present during October, 1975, when the dark-eyed junco dominated relative abundance (68.1%). Four species were recorded on winter censuses. The December sample included only five scrub jays, while the February sampling period disclosed a more diverse, denser avian community. During February a large mixed flock of mountain chickadees, plain titmice, and red-breasted nuthatches comprised 98% of the total relative abundance. Two scrub jays were also observed at this time.

As indicated by strip transect and qualitative survey data, the scrub jay commonly occurs in mixed brush and pinyon-juniper stands on and near Tract C-a. It utilized the pinyons, junipers, and oaks as sites for building its large nests. The red-breasted nuthatch has been recorded as a summer and winter resident within the Douglas fir type and as a winter resident in the north slope pinyon-juniper type on the study area.

The spring sampling period failed to reveal any bird activity. Harsh weather conditions experienced throughout the April period of censusing may partially explain low bird numbers in areas where higher densities were expected.

Thirteen species were recorded on the June strip transect census. The chipping sparrow (6.2 birds/ha), mountain chickadee (1.6 birds/ha), and black-throated gray warbler (1.2 birds/ha) accounted for 77% of the total estimated population density for this stand. Northern slope pinyon-juniper woodlands which support a dense shrub understory provide ideal nesting habitat for the chipping sparrow. The mountain chickadee and black-throated gray warbler both nest in coniferous forests (Bent, 1963a). The mountain chickadee is a common species in the pinyon-juniper woodland throughout the year, while the black-throated gray warbler is generally a common summer resident (Davis, 1969). The grasshopper sparrow (0.2 birds/ha) observed and heard singing during June must be considered highly unusual in this habitat.

7) Pinyon-Juniper (Transect #9) - Fifteen species were tallied in the southern slope pinyon-juniper transect (7,000 ft) in six censuses from October, 1974 through October, 1975.

Twelve species were present during the breeding season, but few individuals or species were observed utilizing this woodland during other periods of the year. The scrub jay was encountered in more seasons than any other species, but was never present in abundance.

During the two fall sampling periods, three species were recorded. A scrub jay and a mountain chickadee were observed during October, 1974, and mountain bluebirds (88.9%) and scrub jays (11.1%) were in this pinyon-juniper woodland the

following fall. The species diversity index for October, 1975, was low in comparison with other transects surveyed, but was higher than most transects in October, 1974. No birds were tallied during either winter census.

During April, a flock of pinyon jays contributed 8% of relative abundance at this transect. Only two other species were observed. No pinyon jays nested in either of the censused pinyon-juniper communities during 1975.

The sparse, mature stand of pinyon-juniper on Transect #9 supported a relatively diverse avian population during June, in contrast to the poor diversity recorded for this vegetation type during other seasons. Twelve species inhabited this pinyon-juniper stand during the summer. The most abundant nesting species were the bushtit (1.2 birds/ha) and mountain bluebird (1.6 birds/ha). The bushtit inhabits the pinyon-juniper woodland of western Colorado. It is found in rugged, dry canyons where it nests in pinyons, aspen, tall sagebrush, mountain mahogany, and cottonwood-willow river bottoms (Bailey and Niedrach, 1965). The other species attaining greatest relative abundance are all characteristic nesting species of pinyon-juniper habitat.

Although little variation occurred between the number of species supported by the two pinyon-juniper transects (#9 and #10) throughout the year, the species found within each transect were not similar. Only five of the 12 breeding species in the southern slope stand (#9) occurred in northern slope pinyon-juniper (#10). This variation in species composition between the two stands may be partially attributable to the denser understory present in the northern slope stand. The north slope pinyon-juniper vegetation type provides more suitable habitat for those species associated with a woodland understory (e.g., green-tailed towhee, Brewer's sparrow, and chipping sparrow). The south slope pinyon-juniper vegetation type is located near small cliffs and a stream, both prime nesting sites for the flocks of white-throated swifts (0.1 birds/ha), that aerially feed on the transect's local insect population.

8) <u>Pinyon-Juniper/Sagebrush (Transect #6)</u> - One hundred forty-one birds, representing 18 species were recorded for the pinyon-juniper/sagebrush transect in six census from October, 1974 through October, 1975. No species was

particularly abundant throughout the year; the mountain bluebird was the only species recorded during three or more sampling periods. Except for three mountain chickadees tallied during December, no wintering birds were observed.

Nine species were present in the pinyon-juniper/sagebrush type during two October censuses. A large flock of 70 horned larks was recorded during October, 1974, along with a small flock of six mountain bluebirds, one scrub jay, and one mountain chickadee. This preponderance of horned larks produced a low diversity index. By contrast, seven species having a relatively high equitability were present in October, 1975 resulting in a high species diversity index. In October, 1975 the bushtit, rufous-sided towhee, and sage sparrow comprised 91% of the total relative abundance. The bushtit, an extremely gregarious bird which often congregates in groups of 40 to 50 individuals (Bent, 1964c), was observed flocking in the pinyon pines and junipers. The rufous-sided towhees and sage sparrows were observed in the sagebrush understory.

The rufous-sided towhee is an uncommon resident of brush and Gambel oak on the Western Slope and during the winter is generally confined to valleys. The rufous-sided towhee has not been recorded in the study area during the winter, but has been observed in small numbers in mixed brush communities throughout the remainder of the year.

The sagebrush sparrow has been recorded in sagebrush and mixed brush types only during the fall; due to its secretive behavior, it is difficult to detect unless it is engaging in flocking, so the possibility of individuals nesting within this sampling area nonetheless exists.

The mountain chickadee was the only species observed in this transect during the winter sampling periods. Three individuals were recorded during December and none was seen during February. No birds were recorded on transect #6 during the spring census.

The stand of mixed pinyon-juniper and sagebrush supported a variety of breeding birds indicative of woodland and/or brushland communities in northwestern Colorado.

Species such as the Brewer's sparrow (1.6 birds/ha), blue-gray gnatcatcher (1.2 birds/ha), and green-tailed towhee (0.8 birds/ha), are typically associated with brush communities (Bent, 1964a, 1968); all three were common in the pinyon-juniper/sagebrush type during June. The pinyon pines and junipers of the area attracted feeding tree swallows (0.2 birds/ha), and cliff swallows (0.4 birds/ha), and nesting mountain bluebirds (1.2 birds/ha). The other common summer resident, the lark sparrow (0.8 birds/ha), was associated with open patches of grasses and forbs within this vegetation type. The blue-gray gnatcatcher is a common summer resident of western Colorado's sage, pinyon-juniper, and mixed brush (Davis, 1969).

The tree swallow is a common summer resident throughout Colorado (Bailey and Niedrach, 1965). It is a cavity nester (Scott and Patton, 1975) and probably utilizes pinyon pines and junipers as nest sites, for it was observed rather commonly near or in the pinyon-juniper woodland type throughout the summer. The cliff swallow is also a common summer resident in western Colorado, nesting on cliffs, buildings, and bridges (Davis, 1969). It is a common summer resident along the drainages in the study area, probably nesting in the many rock outcroppings associated with drainages. The cliff swallows observed within this transect were feeding on the local insect populations, but were probably not nesting due to a lack of suitable nest sites within the transect. However, small cliff faces are located 0.8 km (0.5 mi) south of the transect along the right fork of Stake Springs Draw. This area could support a nesting population of cliff swallows.

The June species diversity index for this transect was high in comparison with other transects. The pinyon-juniper/sagebrush transect is an ecotone (a place where two distinct communities intergrade); ecotones tend to contain a relatively large number of species because they often contain many of the organisms of each of the overlapping communities in addition to those organisms which are characteristic of and often restricted to the ecotone (Odum, 1971).

9) Pinyon-Juniper/Mixed Brush (Transect #4) - Thirty-one birds of 11 species were recorded within the pinyon-juniper/mixed brush transect (northern slope, 7,400 ft elevation) during six censuses. The black-billed

magpie was the only species observed during more than two seasons. During winter and spring, no birds were present along this strip transect.

During the two fall sampling periods, seven species were recorded. The black-billed magpie (11.1% and 2%, respectively), and dark-eyed junco (88.9% and 32.3%, respectively) were observed during both fall censuses. Five other species were also recorded during October, 1975, when the mountain chickadee and dark-eyed junco were the most common.

Seven species (19 individuals) were observed along this transect during June. No one species numerically dominated the avian community during summer; mountain bluebirds (1.2 birds/ha), green-tailed towhees (0.8 birds/ha), and Brewer's sparrows (0.8 birds/ha) were the most frequently observed species.

The green-tailed towhee is a common summer resident of western Colorado. It prefers Gambel's oak and serviceberry stands and is a rare winter resident in the valleys of western Colorado (Davis, 1969). It is found in all types of brushland within the study area during the breeding season and is one of the study area's most abundant summer residents.

The species diversity index for the June census conducted in the pinyon-juniper/mixed brush transect was considerably lower than the species diversity index for the June census conducted within the pinyon-juniper/sagebrush transect. The species diversity indices computed for the other surveys conducted within these two transects either demonstrate slightly higher values for the pinyon-juniper/mixed brush transect or equal values for both transects. (See Table 3-7-250 in the Second Annual Report, RBOSP, 1976, for species diversity and equitability indices.)

10) Sagebrush (Transect #2) - During six surveys from October, 1974 through October, 1975, 27 birds of seven species were recorded in this big sagebrush stand at elevation 6,500 ft. More species were present during the summer than during migration periods, and no birds were tallied on two winter censuses. The community had the lowest cumulative breeding bird density of the 15 vegetation types censused for birds (2.1 birds/ha).

Three species were recorded during the two fall sampling periods. The sage sparrow was recorded during both censuses (100% and 12.8%, respectively, while the horned lark (12.8%) and mountain bluebird (74.5%) were noted only during the October, 1975, survey.

During summer, low numbers of lark sparrows (0.8 birds/ha), Brewer's sparrows (0.7 birds/ha), vesper sparrows (0.3 birds/ha), and lark buntings (0.2 birds/ha) were recorded. This is the only location where lark buntings were observed during the first year of field censuses.

11) Sagebrush (Transect #11) - Sixty birds of 12 species were recorded during five censuses of the big sagebrush vegetation type. This transect traversed a north-facing slope at 7,100 ft elevation. The transect was not sampled during December, 1974 because of adverse weather conditions. No species were observed during the October, 1974 census, but eight species were tallied during October, 1975. The yellow-rumped warbler, mountain bluebird, and vesper sparrow comprised 92.8% of the fall population estimated total relative abundance.

The yellow-rumped warbler is one of the most common and conspicuous birds on Tract C-a during the fall, when it is often seen in small flocks of eight to ten in a variety of habitats.

According to data, the north slope sagebrush transect (#11) supported a denser and more diverse breeding population than that supported by the sagebrush community at Transect #2. This is partially explained by the denser sagebrush cover and the more diverse herbaceous layer which was evident at Transect #11. A more diverse plant community should generally supply more available micro-habitats, thereby promoting a greater diversity of bird species.

12) Greasewood/Sagebrush (Transect #8) - The strip transect which censused the greasewood/sagebrush (flat 6,400 ft) vegetation type was surveyed six times during four seasons between October, 1974 and October, 1975. One hundred thirty-one birds of 21 species were recorded. No species was consistently abundant throughout the year, and virtually no birds inhabited the

transect area during winter. During the two fall sampling periods, 12 species were observed. Yellow-rumped warblers (54.1%), song sparrows (32.4%), and white-crowned sparrows (13.5%) were the only birds recorded during October, 1974, but ten species were observed on the October, 1975 census. The mountain bluebird, Brewer's sparrow, and vesper sparrow were the most abundant species in fall, 1975, cumulatively attaining 72% RA.

The only species recorded during the winter sampling periods was a single scrub jay observed during December. Species diversity increased during the April sampling period when four species were recorded, including a large flock of 22 dark-eyed juncos and 22 gray-headed juncos.

Of the 12 species recorded in this greasewood/sagebrush stand during June, the Brewer's sparrow (4.1 birds/ha) and chipping sparrow (2.5 birds/ha) together accounted for 65% of the relative abundance. This stand supported the largest population of Brewer's sparrows of any strip transect surveyed during June. Brewer's sparrow is one of the most common breeding birds on and close to Tract C-a.

During the April sampling period, chipping sparrows have been observed within the study area during qualitative surveys conducted in the mixed brush vegetation type in Corral Gulch. They have also been recorded as a common summer resident of the pinyon-juniper woodland vegetation type during qualitative surveys.

None of the species observed during June, with the exception of the scrub jay, was recorded on this transect during the winter or spring censuses, nor were any gray-headed or dark-eyed juncos, birds characteristic of this vegetation type in the winter, recorded during the June survey. This and examples from most other transects illustrate a seasonal theme which characterizes avian community dynamics in this part of the nation -- that of a high seasonal turn-over of species utilizing habitats during summer and winter. A high percentage of breeding species in the Piceance Basin migrate to more southern areas for the winter.

13) Rabbitbrush (Transect #3) - One hundred thirty-five birds of 17 species were recorded on six censuses at Transect #3. The mountain bluebird was observed during more sampling periods than other species (October, 1974, April, 1975, June, 1975, and October, 1975). Winter and spring censuses recorded low densities.

Ten species were recorded during the two fall sampling periods. The species diversity index for this transect was the second highest of all transects for October, 1974. Eight species were recorded during October, 1975, when the white-crowned sparrow and mountain chickadee comprised 63.3% of the total relative abundance for this sampling period. Five species were recorded during October, 1974. The mountain bluebird, gray-headed junco, and white-crowned sparrow accounted for 77% of the total relative abundance during this sampling period.

No birds were recorded during the December sampling period but 29 birds representing three species were recorded during February. A flock of 25 bushtits accounted for 88% RA for this sampling period. The bushtit is a fairly common resident of the brush and pinyon-juniper vegetation types in the study area.

Only two species, the mountain bluebird (83.3%) and rufous-sided towhee (16.7%) were recorded during the April census. Both were present in relatively small numbers.

Six species were recorded during June, when the Brewer's sparrow (3.7 birds/ha) and green-tailed towhee (0.8 birds/ha) together comprised 84% RA. A small flock of seven cliff swallows (0.4 birds/ha) and one rough-winged swallow (0.1 birds/ha) was also observed traversing the transect, feeding on flying insects.

14) Riparian (Transect #15) - The strip transect which traversed riparian habitat was surveyed five times during four seasons. This transect was not sampled during the December census period due to adverse weather conditions. Twenty-seven species were recorded during the five sampling periods. The red-winged blackbird, yellow-rumped warbler, and mountain bluebird were the most abundant species recorded on an annual basis. No birds were seen at this location during the February census.

Ten species were recorded during two autumn censuses. Seven species were observed during October, 1974, with the yellow-rumped warbler, mountain bluebird, and mountain chickadee most abundant (90% RA). During October, 1975, six species were recorded and the yellow-rumped warbler and the white-crowned sparrow comprised 93% of the relative abundance. The species diversity index did not vary significantly from the October, 1974 sampling period.

A substantial increase in bird numbers occurred between the February and April censuses. Thirteen species were recorded during April in the riparian transect, whereas no birds were tallied during the winter census. The most abundant species during April were gray-headed juncos (42.1%), dark-eyed juncos (21.1%), mountain bluebirds (14.0%), and red-winged blackbirds (12.6%). This transect attained the highest species diversity for all transects during the April sampling period.

The variety of birds occupying the riparian transect during the June census period is indicative of the heterogeneity of habitat along this portion of Stake Springs Draw. During the June survey, 14 species were noted. The total population was numerically dominated by song sparrows (6.2 birds/ha), red-winged blackbirds (9.8 birds/ha), and Brewer's sparrows (4.9 birds/ha).

The song sparrow is a common summer resident in brush and thickets near water, and less common in these habitat types during the winter (Bailey and Niedrach, 1965). The harsh winter conditions generally prevalent throughout the Piceance Basin undoubtedly limit the area's wintering song sparrow population. Only two sparrows have been recorded during the winter within the study area; these were observed in Ryan Gulch during a qualitative survey.

The red-winged blackbird is a common summer resident along the creeks in the study area, but has not been recorded during the winter. The density of red-winged blackbirds tripled between April and June, 1975. Male red-winged blackbirds migrate during March and April and establish territories before females arrive. During the April census, males were present but few females had appeared. The species is polygamous, and the male can form simultaneous pair bonds with four or five females.

The riparian type supported the second largest number of species of all transects during June; nonetheless, the species diversity index was not one of the largest because of the preponderance of only three breeding species. Four species of waterbirds were also noted on strip censuses of this habitat.

15) Bottomland Meadow (Transect #1) - The bottomland meadow (flat/6,300 ft) strip transect was surveyed six times during four seasons. Twenty-three species were recorded for the entire year. No species was particularly abundant throughout the year. During the two fall censuses, seven species were recorded, three species during 1974 and four during 1975. Horned larks comprised 82% of the relative abundance during the October, 1974 census. A water pipit and black-billed magpie were also recorded. Western meadowlarks, red-winged blackbirds, and mountain bluebirds numerically dominated the estimated avian population (97% RA) during October, 1975.

Four species were recorded in low numbers during the winter. Two species, the black-billed magpie (40%) and common raven (60% and 26.7%, respectively) were observed on both winter censuses. The horned lark (6.7%) and tree sparrow (26.7%) were also recorded during February. These species are all winter residents of the meadows and brushland within the study area. Five species were present during April including a single western wood pewee. The western wood pewee is normally a common summer resident of western deciduous and coniferous forests (Davis, 1969), but it is known to nest in Colorado from the prairies to elevations of 10,000 ft (Bailey and Niedrach, 1965). The presence of this species during April and the absence of sightings during the breeding season suggest the bird was a migrant which stopped to feed in the riparian vegetation before proceeding on to forested country to nest. The western wood pewee was sighted within the pinyon-juniper/sagebrush vegetation type during June. The pinyon pines and junipers are likely nesting sites for this pewee, as are the aspen and Douglas fir vegetation types within the study area.

The influx of species to the bottomland meadow transect between April and June sampling periods was substantial, and 19 species were observed during June. The estimated population densities of most species were small. All were in the

range of 0.1 to 0.9 birds/ha. All species encountered during June can be expected to inhabit meadows, pastures, and riparian vegetation types on Colorado's western slope (Davis, 1969). During June, this habitat achieved a higher maximum diversity than any other transect attained in any season.

b. Upland Gamebirds

1) Sage Grouse - Opportunistic sightings of sage grouse were recorded during all field activities. Aerial surveys were conducted in April to locate sage grouse strutting grounds (leks) in the tract vicinity. The first survey was conducted on April 25 over 84 Mesa; the second covered an area west of Tract C-a. Results of two brood censuses conducted in the vicinity to investigate sage grouse nesting success have shown both areas to be inhabited by sage grouse. These were conducted July 14-15, 1975 along a 32 km (20 mi) route located in sagebrush and mixed brush vegetation types, the preferred nesting habitats for sage grouse (Patterson, 1952).

During fall and winter field activities, 24 sage grouse were observed in sagebrush habitat on the eastern slopes of Cathedral Bluffs. Opportunistic sightings during fall, 1975 provided records of sage grouse in two other locations. Two sightings, the first of four and the other of one grouse (all adults), were recorded on the ridge northwest of the right fork of Stake Springs Draw within a sagebrush/mixed brush vegetation type. Four sage grouse (all adults) were reported on Cathedral Bluffs within a mountain shrub community.

The two aerial surveys revealed the presence of two strutting grounds west of Tract C-a. The first lek was occupied by 27 sage grouse (20 males, seven females) and the other was occupied by six sage grouse (four males, two females). Both leks were in open areas surrounded by sparse sagebrush cover. Sage grouse strutting grounds were not observed on 84 Mesa. Mr. Ronald J. Krager, Wildlife Conservation Officer for the Colorado Division of Wildlife, was consulted to obtain information on sage grouse utilization of 84 Mesa. Mr. Krager noted that grouse once utilized an area in Section 19, T1S, R98W for strutting. However, over the last few years, the number of sage grouse using the lek has steadily decreased (Krager, personal communication, 1975). Sage grouse have not been observed displaying in the area during recent surveys.

During the early spring survey period, four sage grouse were observed in sagebrush habitat on the eastern slopes of Cathedral Bluffs. Three sage grouse were flushed from sagebrush habitat on 84 Mesa. None of these sage grouse were on a lek. Four sage grouse (one female, three chicks) were observed during the July 14, 1975 breeding census, and two flocks comprised of seven (two males, one female, four chicks) and 16 (three female, 13 chicks) birds, respectively, were seen during the July 15 census. All sightings were within a 1.6 km (1 mi) segment of the census route on the ridge of the right fork of Stake Springs Draw, within an upland sagebrush vegetation type. Two opportunistic sightings in this vicinity on July 30-31, 1975 involved 27 sage grouse.

Summer observations of sage grouse populations in two other locations within the study area included 13 (11 adults, two juveniles) on Cathedral Bluffs within a mountain shrub vegetation type, and two sightings of five and three sage grouse (adults and young, respectively) on Airplane Ridge within a sagebrush/mixed brush vegetation type. Although nests were not searched for, the repeated sightings of juveniles with adults indicate that sage grouse are nesting and rearing broods near each of the locations indicated above.

Sage grouse have not been observed around any bodies of water, but the birds are probably fulfilling their water requirements by using the intermittent streams located in the valleys between the ridges east of Cathedral Bluffs, and permanent streams such as Spruce Gulch. They probably also utilize snow, dew and rainwater puddles as sources of water.

Rogers (1964) described sage grouse density in the region as "light" and indicated that sage grouse have only been observed in low numbers within sagebrush communities in the Piceance, Yellow and Douglas Creek drainages. Rogers (1964) has recorded them on 84 Mesa, the only area in Rio Blanco County near Tract C-a where they have also been sighted by ECI personnel. A possible explanation for the reported scarcity of sage grouse in Rio Blanco County, according to Rogers (1964), is that a large amount of the sagebrush range in the basin is intermixed with pinyon-juniper, a combination apparently avoided by this grouse. Rogers (1964) also stated that sagebrush in Rio Blanco County occurs in steep, narrow canyons with little available water, habitats not preferred by sage grouse.

Sage grouse are apparently not limited to the sagebrush vegetation type in the study area; rather, they inhabit a variety of upland brush vegetation types on and near Tract C-a. All observations within the tract vicinity indicate a moderate population of sage grouse within the areas of upland sage and mixed brush vegetation types in southwest portions of the study area, and a small population on 84 Mesa. There appears to be little seasonal migration of this population, although this is difficult to gauge because most sage grouse observations are from the spring and summer periods, and few sightings have occurred in winter.

2) Blue Grouse - Records of opportunistic sightings of blue grouse have been maintained throughout the first year. Blue grouse were also censused twice along a standard census route on June 11 and 12 during the blue grouse display season(Rogers, 1968) by procedures outlined earlier.

During fall 1974 and winter 1974-75, only five blue grouse were seen on Cathedral Bluffs, the area expected to support the greatest population of this gamebird. However, blue grouse were observed rather frequently, either opportunistically or during conduct of strip transects, during fall, 1975. The eight encounters, all within a 5 km (3 mi) section of Cathedral Bluffs, included 38 blue grouse. Seven of the eight encounters occurred within, or adjacent to, the Douglas fir and aspen strip transects. During the September 30 - October 5, 1975 small mammal trapping period, 26 blue grouse were observed within the Douglas fir grid and in an aspen stand adjacent to this grid. Four blue grouse were also seen within the Douglas fir grid during the October, 1975 strip transect. One blue grouse was recorded within the aspen transect during the fall census. The only record of blue grouse outside of an aspen or Douglas fir stand during fall 1975 was a sighting of seven blue grouse within an upland meadow vegetation type located a few kilometers south of the Douglas fir small mammal grid.

The Cathedral Bluffs area appears to support a fairly large population of blue grouse. During the road survey conducted June 11-12, 1975, 23 displaying male grouse were tallied. This amounts to 2.4 grouse/km (1.5 mi) of road. This compares to 0.14 grouse/km for the best 2.4 km section of road

surveyed by Rogers (1968) in Colorado over a three-year period. The many opportunistic sightings of blue grouse recorded during 1974 and 1975 (66 birds recorded to date) also suggests that a relatively large population inhabits the Cathedral Bluffs area. This blue grouse population is found year-round on Cathedral Bluffs, but localized seasonal movements apparently occur. During the breeding season, most individuals inhabit the meadow, mixed brush, and aspen/mixed brush ecotone areas. After breeding and resting, the birds appear to move to dense stands of Douglas fir and aspen. However, not all the blue grouse migrate to heavily timbered areas; some individuals were still observed during the fall and winter in meadow and mixed-brush vegetation types. The absence of blue grouse in these habitats during the August survey and the large number of grouse observed on the Douglas fir and aspen small mammal grids during the fall (compared to their absence in these grids during the breeding season) suggest that a portion of the population does migrate. According to Rogers (1968), the timing and extent of these movements are related to food availability and weather conditions.

3) Mourning Doves - Most mourning doves had left the study area by October, as evidenced by the lack of mourning dove observations on strip transect and qualitative censuses in October, 1974 and very few observations in fall, 1975. The few individuals observed during October, 1975 were recorded in riparian and lowland mixed brush vegetation types. Mourning doves had returned to the Piceance Basin by early April and were first observed in the Tract C-a area at 84 Ranch on April 29.

The possibility of an earlier migration into the Piceance Basin cannot be ruled out, since no bird censuses were made during March and early April. Mourning dove fall migrations generally begin at the end of August; usually only scattered individuals are observed in breeding locales after mid-September. By the June census periods, the mourning dove appeared to be a common summer resident in the pinyon-juniper and greasewood/sagebrush vegetation types. During the June surveys, 17 sightings of mourning doves were recorded in the pinyon-juniper vegetation type, and three in the greasewood/sage vegetation type.

The mourning dove is the most widely distributed game bird in the Tract C-a vicinity. During general field activities coinciding in time with the breeding season, this dove was observed in many habitats, with the greatest number of observations in pinyon-juniper and greasewood/sagebrush vegetation types. The preferred nesting sites of this species are usually close to water and trees, so actual breeding habitat tends to be more restricted than the range of vegetation types the mourning dove is capable of exploiting if water is well distributed. Trees are favored sites for roosting, daytime resting, and nesting (Davis and Anderson, 1973). The habitats in the study area most frequented by the mourning dove are thus in or adjacent to woodlands.

Mourning doves are not communal nesters, but they pursue gregarious habits soon after the breeding season terminates. From late July until fall migration, doves congregate in roosting places (Bent, 1963b). The pinyon-juniper woodland vegetation type in the study area provides many of these communal roosting sites for the mourning dove.

c. Waterfowl and Shorebirds - The Stake Springs Draw impoundment received light usage by waterbirds during fall 1974 and 1975 migration periods. During October, 1974 only the mallard was observed at the impoundment, and only 15 individuals of four species (mallard, green-winged teal, blue-winged teal, killdeer) were seen at the impoundment during counts made between October 6 and 13, 1975. During other field activities in September and October, 1975, 23 blue-winged teal, one killdeer, one common snipe, and nine mallards were observed at the Stake Springs Draw impoundment. The Piceance Basin is not recognized as a segment of any major migratory route within the Pacific waterfowl flyway, the major flyway west of the Continental Divide (Dr. Ronald A. Ryder, personal communication, 1975). This, plus the paucity of water in the Tract C-a vicinity, accounts for the scarcity of waterfowl observed during fall migration.

During spring, when more water is available, increased waterfowl utilization of the area occurs. In April, 1975, ducks were present in Stake Springs Draw, Ryan Gulch, and Black Sulfur Gulch, and 54 birds consisting of mallards, green-winged teal, and blue-winged teal were seen at the Stake Springs Draw impoundment.

A total of five duck and eight shorebird species was observed during the two summer sampling periods. In June, 11 species were recorded at the Stake Springs Draw impoundment. The mallard, green-winged teal, and common snipe were the most abundant. Wilson's phalarope, killdeer, spotted sandpiper, gadwall, cinnamon teal, sora, Virginia rail and blue-winged teal were also present, but in lower numbers. The semi-palmated plover, long-billed curlew and white-faced ibis were also recorded during general avian surveys in June.

Waterbird abundances were relatively high during the August census period when a total of 62 birds was recorded. However, only four species, the mallard, killdeer, American avocet, and solitary sandpiper were present on the impoundment. The mallard was the most abundant species recorded during the August survey, and was observed during every count. On one morning, 35 mallards were observed feeding in the pond. The large numbers of mallards present during mid-August may be due to pre-migration flocking. Although the migration flights do not begin in earnest until late September, flights from local nesting areas to nearby feeding grounds occur in late August or early September (Kortright, 1967). Perhaps many of the mallards that nest in the Tract C-a vicinity congregate and feed in the Stake Springs pond before migrating south.

Results from the year's surveys indicated that usage of the area by ducks and shorebirds is greater during late spring and summer than during fall, but that waterbird populations within the general area are very low. Considerably more ducks were observed along Piceance Creek and its associated ponds (Woodward-Envicon, Incorporated, 1974; Woodward-Clyde, Consultants, 1975a, 1975b, 1975c) than were seen within the Tract C-a study area. The scarcity of open water within the study area is undoubtedly the major limiting factor on the size of the resident and migratory waterfowl population.

In summary, the mallard, green-winged teal, blue-winged teal, killdeer, and common snipe are the most common waterfowl and shorebird species found within the study area. The Stake Springs impoundment and the riparian habitats within the study area support a small breeding and migrating population of these species.

d. Raptors

1) Aerial Surveys - Raptor aerial surveys were initiated during November, 1974 and were continued bimonthly until August, 1975. Raptor aerial surveys were not conducted during October, 1975 due to inclement weather and big game hunting seasons. Relative abundance for each sampling period and the entire year are also presented. However, the few small raptors recorded during aerial surveys are not a fair indication of the relative abundance of these birds on the study area, since small, low-flying raptors such as accipiters and falcons are difficult to detect from an aircraft.

The common raven was the most abundant raptor species, attaining 58% RA through the year. This species was encountered on every raptor survey. The golden eagle and rough-legged hawk were observed less frequently, but were the only other species with a relatively high RA percentage. Golden eagles were recorded during every survey except the one conducted during June.

The rough-legged hawk is a winter resident in the Piceance Basin and was commonly observed between November, 1974 and February 1975. The northern bald eagle was recorded once during February. The marsh hawk, Cooper's hawk, and American kestrel were observed in small numbers, but these species are not easily censused by airplane due to their small size and/or low flying habits. The marsh hawk was observed once during November and April; the Cooper's hawk was observed once during the spring and once during the summer, while the American kestrel was observed once in June and three times in August.

The red-tailed hawk was not recorded frequently during the aerial surveys but was commonly recorded during ground investigations. One peregrine falcon was also observed during an April flight. The status of all the raptor species observed in the Tract C-a study area is discussed later in detail.

The distribution of raptor sightings demonstrates certain interesting trends. Most raptors were recorded within the eastern half of the study area and along the drainages. The raven was most frequently observed along Yellow Creek and 84 Mesa during the winter and spring. The majority of golden eagles was

observed during the winter along Cathedral Bluffs. All rough-legged hawks, with the exception of one observed on Cathedral Bluffs, were recorded east of Tract C-a. The other raptor species have been observed too infrequently to speculate on distributional tendencies.

2) Ground Surveys - Raptors noted during all avian field activities conducted between October, 1974 and October, 1975 were recorded by species and location of observation. In the course of field investigations, all raptor nests encountered were examined and their location plotted on field maps. During late April and early June, potential raptor nesting habitats on Tract C-a and the surrounding areas were traversed on the ground for four consecutive days to locate active nests.

Night owl surveys were initiated in December, 1974 and were repeated during April, 1975. Surveys were conducted on two nights during the two sampling periods.

3) Status of Raptor Species in the Tract C-a Study Area

a) Turkey Vulture - Two turkey vultures were observed in the study area during summer and fall, 1975 sampling periods. This species is highly migratory within the western states (Brown and Amadon, 1968) and the majority of individuals leave Colorado by late September (Bent, 1961). The one individual observed during fall was probably a straggler. Turkey vultures have not been observed near Tract C-a during the winter.

The turkey vulture utilizes many habitat types and hunts over a wide area. Carrion comprises most of its diet, although it will kill young mammals and has been known to feed in insects (Grossmand and Hamlet, 1964). Its presence on Tract C-a and adjacent areas during the breeding season indicates that it is probably nesting in small numbers in the vicinity. No nests have been encountered, but potential nest sites exist on Tract C-a and adjacent areas. The preferred nesting sites are generally located in places inaccessible to predatory animals, or where the eggs and/or young cannot easily be reached

(Bent, 1961). These sites tend to be cliffs, caves, hollow stumps, or in the midst of dense shrubbery (Bent, 1961; Brown and Amadon, 1968). In such locations, the vulture lays its eggs with little or no attempt to construct a nest (Bent, 1961).

b) Northern Bald Eagle - The bald eagle was observed within the study area during February but was not observed again through the remainder of the winter. This eagle was observed by field personnel within other areas of the basin along Piceance Creek during March, so it appears to be an uncommon winter resident of the Piceance Basin. Bald eagles were not recorded after March. The subspecies winters as far north as open water and food are available (Brown and Amadon, 1968). It nests only rarely in Colorado; most northern bald eagles nest in northern North America (Grossman and Hamlet, 1964). Tract C-a and environs do not provide suitable nesting habitat for this species since it prefers tall trees or large cliff faces in proximity to water (Bent, 1961; Brown and Amadon, 1968). Cathedral Bluffs, an area west of Tract C-a, provides possible nesting sites, but the rarity of the northern bald eagle as a Colorado summer resident indicates that it is an improbable nesting species along the Bluffs.

c) Golden Eagle - Golden eagles have been recorded within the study area throughout the year. This species hunts over open country and shows a strong preference for mammals in its diet (Brown and Amadon, 1968). According to results of a current study on the status of the golden eagle in western states (Boeker, 1974), the golden eagle population in Colorado, on a year-round basis, is 5.3 eagles per 1,000 sq. mi. This is one of the highest densities among the western states. The Tract C-a vicinity included the ranges of at least four adult golden eagles during the 1975 breeding season; probably a few additional birds winter within the study area. Two active nests were located on the study area but off of the tract itself. Each nest contained a single eaglet. It is difficult to ascertain from the total number of golden eagle sightings recorded outside of the breeding season how many individual golden eagles were actually observed. The home range of a golden eagle varies from 19 mi^2 in California to 200 mi^2 in heavily forested areas located in northeastern

North America (Brown and Amadon, 1968). The home range size is dependent on such factors as prey density, season, and percentage of the range suitable for hunting (Brown and Amadon, 1968; Gordon, 1955).

d) Marsh Hawk - Field activities during 1974 and 1975 have substantiated that the marsh hawk is a fairly common raptor during the breeding season but is infrequently observed during the winter. To date, three marsh hawk nests have been located in the study area. The marsh hawk is a bird of open fields and marshes and avoids heavily forested areas (Burleigh, 1972). This species is a ground nester. The Tract C-a area probably supports more pairs than the three noted during 1975, but the nest of this species is difficult to locate because of the marsh hawk's preference for placing its nest on the ground in tall grass and shrubs. The pastures and sparsely vegetated mountain shrub stands within the study area provide suitable nesting habitat for this harrier.

This hawk is a migratory species in some parts of its geographical range, and a year-round resident in other areas (Bent, 1961). Davis (1969) describes the marsh hawk as an uncommon summer and common winter resident in western Colorado. Our data indicate that within the study area, the marsh hawk is a common summer resident and an uncommon winter resident.

e) Sharp-Shinned Hawk - Only one sharp-shinned hawk, recorded during summer 1975, has been observed on the study area. Davis (1969) described the sharp-shinned hawk as a common winter and rare summer resident. This accipiter prefers to nest in dense stands of conifers (Brown and Amadon, 1968; Grossman and Hamlet, 1967). There is little suitable nesting habitat for this small accipiter within the study area, but the open nature of much of the area should make it attractive as winter habitat for sharp-shinned hawks. Its apparent absence from the study area during the winter does not correspond with some of the literature for western Colorado (Davis, 1969). Until further field investigations are completed, it must be concluded that the status of the sharp shinned hawk in the region is uncertain.

f) Cooper's Hawk - The Cooper's hawk has been observed fairly frequently during the spring and summer. It has not been recorded during fall and winter, but it has been observed during the fall in areas close to Tract C-a by field personnel. Davis (1969) described the Cooper's hawk as a common winter resident in western Colorado. The Cooper's hawk is principally a woodland species (Burleigh, 1972) but it also nests in large shrubs such as Gambel oak (Bent, 1961). Two nests have been found within pinyon-juniper woodlands in the Tract C-a area.

g) Goshawk - One pair of goshawks has been observed at their nest in an aspen grove along Cathedral Bluffs. Davis (1969) described this species as a rare resident of heavily wooded areas in western Colorado. Twomey (1942) indicated that the goshawk ranges from aspen habitats to timberline in eastern Utah. The goshawk generally nests in dense coniferous or deciduous forests adjacent to clearings (Brown and Amadon, 1968), where it feeds on large and medium-sized birds and mammals. Bent (1961) stated that, unlike other accipiters, the goshawk showed a definite preference for deciduous woods. Due to the scarcity of dense deciduous forests in the study area, the nesting goshawk population is probably small and limited to the Cathedral Bluffs area. This species has not been recorded during the winter.

h) Red-Tailed Hawk - Although few red-tailed hawks have been observed during aerial censuses, ground observations indicate this buteo is one of the most common raptors in the study area. The adult red-tailed hawk is opportunistic in its predatory habits, feeding on a variety of small mammal species. Its population levels generally fluctuate with changes in the local prey density (Craighead and Craighead, 1969). Brown and Amadon (1968) suggest the red-tailed hawk has the widest ecological tolerance of any buteo and perhaps of any hawk in North America. It resides in a greater variety of habitat types and has one of the widest distributions of any hawk in North America. The species does, however, show a preference for ecotone areas supporting trees (Brown and Amadon, 1968). This phenomenon is illustrated within the study area, where the red-tailed hawk frequents the various drainages with mixed brush bottoms and adjacent pinyon-juniper slopes. Its favored nesting site in the area is sandstone cliffs associated with pinyon-juniper woodlands, but an

occasional nest is located in a mature pinyon pine or juniper. Six red-tailed hawk nests were located on the study area during April. All contained two or three eggs. Red-tailed hawks are most abundant during the spring and summer, but a few individuals over-winter within the study area.

i) Swainson's Hawk - One Swainson's hawk was observed during summer, 1975. Both Davis (1969) and Twomey (1942) refer to this species as an uncommon summer resident and migrant in western Colorado and eastern Utah. Davis (1969) stated that occasionally a few Swainson's hawks winter in western Colorado.

j) Rough-Legged Hawk - Rough-legged hawks are common wintering raptors in the Tract C-a vicinity. This hawk appeared in the area by late November, 1974 and remained through the winter. Davis (1969) reported this species as an uncommon winter visitor in western Colorado and Twomey (1942) observed rough-legged hawks in the Uinta Basin, Utah only during migrations. According to Craighead and Craighead (1969), the presence of these birds in large numbers may indicate high populations of small rodents, which comprise the majority of this species' diet. The rough-legged hawk departed the Piceance Basin sometime between mid-March and early August. Bent (1951) explained that the melting snow reveals the runways of voles, the major prey species of the rough-legged hawk.

k) Prairie Falcon - Seven sightings of prairie falcons have been recorded within the study area. The prairie falcon is a cliff nester and inhabits treeless areas, nesting rarely up to 12,000 ft elevation. The actual nest site is usually a ledge with some overhand, a pothole, or a cave (Brown and Amadon, 1968). Although no eyries have been recorded, the possibility of a pair of prairie falcons nesting within the study area exists. The most suitable nesting sites are the cliff faces along the western edge of Cathedral Bluffs. The rest of the study area shows poor nesting potential for this species. The prairie falcon is an uncommon nester in northwestern Colorado.

The Colorado Division of Wildlife's ongoing raptor survey has identified a few eyries within the Piceance Basin north of the study area. Mr. Gerald Craig,

Chief Raptor Biologist for the Division, indicated that the nesting prairie falcon population is sparse, and he does not think it is likely that many eyries exist in northwestern Colorado (personal communication, 1975). Until recently this falcon was classified as "threatened" by the Federal government.

In winter, the prairie falcon moves to lower, windswept, winter wheat areas, where horned larks concentrate. Horned larks constitute the principal winter food of this falcon (Brown and Amadon, 1968). The numerous horned larks occurring on the study area during winter might explain the presence of the one prairie falcon recorded in December. The presence of this bird indicates that it is a rare winter resident within the study area.

1) Peregrine Falcon - The peregrine falcon, classified as an endangered species (United States Department of the Interior, "Threatened Wildlife of the United States," 1973), was observed four times within the study area during spring and summer 1975. The peregrine falcon is considered a rare resident breeder in northwest Colorado (Bailey and Niedrach, 1965). Mr. Gerald Craig (personal communication, 1975) noted that this species has nested and fledged young from eyries in northern Colorado and possibly nests in an area about 32 km (20 mi) southeast of Tract C-a. Enderson and Craig's (1974) treatise on the status of the peregrine falcon in the Rocky Mountains demonstrated that this species has experienced a population decline over the last few decades. The likelihood of a peregrine falcon nesting within the study area is remote, due to the lack of large cliff faces and the paucity of water within the area (G. Craig, personal communication, 1975).

The peregrine falcons observed during April and August may have been migrants. The species' northerly migration from Central and South America generally takes place in March and April (Brown and Amadon, 1968). The peregrine falcons observed during July could have been unpaired individuals or nesting adults. According to Mr. Craig (personal communication, 1975), a peregrine falcon could possibly hunt 33 km from its eyrie, so these individuals could have been associated with the suspected eyrie located within this radius of Tract C-a.

m) Merlin - The merlin was recorded five times during the October, 1975 sampling period within bald and mixed brush vegetation types. It has not been recorded during other sampling periods. This falcon is a rare winter visitor in western Colorado and was formerly a summer resident of the region (Davis, 1969). It is a bird of open country and is seldom found within forested areas unless there are large open spaces interspersed in the stand (Brown and Amadon, 1968). It preys chiefly on small birds, especially the inhabitants of the ground or low vegetation such as horned larks and finches (Brown and Amadon, 1968). The merlin's major breeding range is north of the continental United States. The majority of merlins winter in the southern United States, the Carribbean, and northern South America (Bent, 1961). However, eastern Colorado supports a small wintering population.

The height of the fall migration is between mid-September and mid-October, coinciding with the height of songbird migration (Bent, 1961; Brown and Amadon, 1968). The individuals recorded on the study area during fall, 1975 were probably migrants, resting and feeding on Cathedral Bluffs for a few days.

n) American Kestrel - The American kestrel, one of the most abundant raptors encountered during the spring, summer, and fall, was observed throughout the study area. Seven kestrel nests have been located. The four nests found during April each contained one or two eggs and the three nests located in June each contained two or three chicks. Unlike most falcons, the kestrel will nest in deserted woodpecker holes and hollow trees as well as on cliff faces (Craighead and Craighead, 1969; Cooper, 1974). The small cliff faces scattered throughout the sampling area and the stands of pinyon-juniper woodland could support a substantial nesting population of kestrels. The kestrel's diet during the breeding season consists primarily of mice, small birds, and insects (Craighead and Craighead, 1969). Kestrels have been observed in low numbers in the study area during winter. A number of authors (Bent, 1961; Heintzelman and Nagy, 1968) have suggested that a low percentage of American kestrels over winter within their breeding areas. This depends primarily on food availability; their winter diet generally consists largely of meadow mice (Craighead and Craighead, 1969).

o) Common Raven - The common raven is the most abundant resident raptor within the study area. It is a fairly common bird of the mountains in western Colorado (Bailey and Niedrach, 1965; Davis, 1969). Three raven nests were located and due to the large numbers of ravens encountered during the summer, many other active nests certainly exist. The preferred nesting site is a crevice in a cliff face (Burleigh, 1972). These nest sites are in such inaccessible places that locating them is often difficult. The raven is primarily a scavenger and commonly competes with magpies and eagles for carrion (Bailey and Niedrach, 1965); however, it also takes prey (Bent, 1964c). They are found in large numbers throughout the year in the study area and are particularly gregarious during winter. It is not unusual to see flocks of 10 or more ravens at one time during the fall and winter.

p) Screech Owl - One screech owl was recorded during the December, 1974 night owl transect. This species prefers well-wooded creek bottoms and open woodland adjacent to grainfields, meadows, brushland, or grassy valleys (Karalus and Eckert, 1974). It is an uncommon resident in western Colorado (Davis, 1969). Screech owls are most active directly after sunset, and feed primarily on frogs and mice. They roost during summer days on branches in heavy tree foliage and in natural tree hollows during winter (Karalus and Eckert, 1974). Although only one individual was recorded on the study area, the screech owl is probably an uncommon resident of the Piceance Basin. It is not a migratory species (Karalus and Eckert, 1974), yet there are times when seasonal movements have been recorded. These movements are largely dependent upon the severity of winter and prey availability (Karalus and Eckert, 1974).

q) Great Horned Owl - The great horned owl is the most abundant nocturnal raptor within the study area. Three great horned owls were recorded during the December, 1974 night owl transects and one was recorded during the April, 1975 transects. Many opportunistic sightings have been made in a variety of habitats throughout the year. This species is a locally common resident in woodlands throughout western Colorado (Davis, 1969). The great horned owl and the red-tailed hawk often inhabit and hunt the same territory, the hawk by day, the owl by night.

Although the great horned owl generally hunts at night, it is apt to be seen on the wing during all times of day. The great horned owl has one of the most varied diets of any North American raptor. It will eat almost any live prey but will rarely scavenge. It shows a preference for rodents, cottontail rabbits, skunks, crows, and other owls (Craighead and Craighead, 1969; Karalus and Eckert, 1974).

The nest of a great horned owl is generally an abandoned red-tailed hawk nest on cliffs or tall trees. The many small sandstone cliffs and stands of pinyon pines and junipers within the study area provide ample nesting sites for this species. Seven great horned owl nests were discovered, all of which contained eggs and/or young. The great horned owl is one of the earliest nesting raptors; its courtship begins in November or early December (Karalus and Eckert, 1974). This species is essentially non-migratory (Orians and Kuhlman, 1956), but during severe winters when prey becomes difficult to find, some seasonal movements occur (Karalus and Eckert, 1974).

r) Pygmy Owl - One pygmy owl was recorded during the December, 1974 night owl transect. Davis (1969) described this species as an uncommon, rarely-observed resident of mountain forests in western Colorado. It sometimes comes down into the lower valleys in winter. It feeds primarily on small and medium-sized birds and small mammals (Karalus and Eckert, 1974). The pygmy owl is a cavity nester and ordinarily uses the abandoned hole of a hairy woodpecker or common flicker (Scott and Patton, 1975). The presence of the pygmy owl during December indicated that this species is a winter resident; due to the paucity of sightings, its status is undetermined.

s) Short-eared Owl - Two short-eared owls were recorded during the December, 1974 night owl transect. The short-eared owl is an uncommon winter visitor to open fields in western Colorado (Davis, 1969) where it feeds primarily on meadow voles. The short-eared owl, unlike the great horned owl and screech owl, is a restricted feeder; it feeds principally on one or two prey species (Craighead and Craighead, 1969; Karalus and Eckert, 1974). Although grassy fields and marshlands are its preferred habitat, the short-eared owl is often found in a variety of habitats ranging

from the alpine tundra to city parks. The short-eared owl does not generally breed in northwestern Colorado (Davis, 1969; Karalus and Eckert, 1974). For complete tabulated avifauna results and figures showing sample locations see pages 3-7-607 through 3-7-639 in the Second Annual Report (RBOSP, 1976)

4. Discussion - The largest number of birds and the greatest number of species encountered during the two fall sampling periods occurred within the rabbitbrush, greasewood/sagebrush, Douglas fir, and riparian vegetation types. The pinyon-juniper (south slope), mixed brush (north slope), upland meadow, and sagebrush (flat) types exhibited a paucity of species and low total numbers of birds during October, 1974 and 1975. The mountain bluebird, mountain chickadee, gray-headed junco, dark-eyed junco, horned lark, white-crowned sparrow, and yellow-rumped warbler were observed in greater numbers than any other species during the autumn surveys.

The October, 1974 sampling period probably occurred near the end of the fall migration for most bird species. Some migrating birds such as the mountain bluebird, western meadowlark, and white-crowned sparrow were still present in the study area. A greater number of summer resident species was present during the October, 1975 census period. The mild fall weather that occurred during 1975 probably resulted in later migratory exodus in comparison with the 1974 fall migration.

The bottomland meadow, mixed brush (south slope), pinyon-juniper (north slope), and Douglas fir vegetation types supported the largest number of birds and the greatest species diversity during the two winter sampling periods. The sagebrush (flat and north slope), pinyon-juniper/mixed brush, pinyon-juniper (south slope), upland meadow, and the greasewood/sagebrush vegetation types exhibited few or no birds during the two winter censuses.

Migratory species encountered in October had departed the area of investigation by winter, while more northern migratory species such as the northern shrike and tree sparrow had migrated into the region after the fall sampling period. The black-billed magpie, common raven, red-breasted nuthatch, and mountain chickadee were the most abundant species within the study area during the winter.

The December census results exemplified the sparseness of birds, which is typical of these portions of the temperate region during late fall and winter. The avifauna encountered during February included species which are probably typical of Tract C-a's habitats during winter. The mid-winter avifauna was comprised of 23 species, all of which were observed in low numbers. The horned lark, pinyon jay, mountain chickadee, red-breasted nuthatch and the tree sparrow comprised about 60% of all individuals observed.

During April, by order of rank, the largest number of birds and the greatest number of species were encountered in the riparian and aspen vegetation types. No birds were observed in the north slope mixed brush, north slope pinyon-juniper, pinyon-juniper/sagebrush, pinyon-juniper/mixed brush and north slope sagebrush vegetation types. Strip transect censuses documented the presence of 27 species during April. Qualitative count surveys along with all other field censuses conducted in early spring accounted for an additional 34 species. The April sampling period occurred near the starting point of the spring migration for most bird species. Many summer residents such as the mourning dove, Say's phoebe, western wood pewee, tree swallow, rough-winged swallow, barn swallow, yellow-rumped warbler, orange-crowned warbler, Virginia's warbler, and green-tailed towhee had appeared in small numbers.

Results of the April censuses were thus a composite of late winter and early spring populations. Many areas showed the uneven pattern of bird distribution typical of the winter, while other areas hosted a considerable variety of species and numbers. Wintering species such as the rough-legged hawk, northern shrike, and tree sparrow had begun migration northward. The tree swallow, rough-winged swallow, barn swallow, pinyon-jay, mountain chickadee, mountain bluebird, yellow-rumped warbler, red-winged blackbird, dark-eyed junco, gray-headed junco, vesper sparrow, and chipping sparrow were the most frequently observed species during the early spring field sampling period. Of these, the mountain bluebird and gray-headed junco were exploiting a wider range of vegetation types than were other species. These 12 species accounted for more than 65% of the birds observed during the early spring surveys.

As with the fall migration period, any census of avian species during a transition stage must be analyzed with caution. During these transitory periods, species migrating in flocks tend to move along certain topographic features such as a drainage, river valley, canyon, etc. Species comprising these flocks generally display a less specific attachment to favored habitat than they exhibit during the breeding season. The uneven distributional pattern of avian species in large areas of favored habitat can further be explained by inclement weather and the tendency for species to form large intermixed flocks during migration (Lack, 1960; Graber and Graber, 1963; Graber, 1968; Brewer, 1972).

During summer, the largest number of birds and the greatest species diversity were encountered within the riparian, bottomland meadow, Douglas-fir, aspen, and all pinyon-juniper vegetation types. The rabbitbrush, sagebrush, mixed brush, and upland meadow vegetation types supported fewer species and low total numbers of birds in comparison with the aforementioned vegetation types. June censuses occurred during the height of the breeding season for most species. The variety of vegetation types present in the study area provided suitable nesting sites for many species, as demonstrated by the relatively high diversity recorded during the summer season. Of the 96 species recorded during this sampling period, 42 species were not present during autumn, winter, or spring censuses. The mountain bluebird, green-tailed towhee, chipping sparrow, Brewer's sparrow, and vesper sparrow were the most frequently observed species during the summer sampling period.

On an annual basis, the riparian community and adjacent habitats supported the greatest bird density and diversity throughout the year, while the sagebrush and rabbitbrush communities supported the lowest number of species and individuals.

In the southwest portions of the study area, a relatively large population of sage grouse exists on a year-round basis within areas of upland sagebrush and mixed brush vegetation types. There also is a relatively large population of blue grouse along Cathedral Bluffs. The blue grouse primarily inhabits upland meadow, mixed brush, and aspen/mixed brush ecotonal areas during the

breeding seasons; during winter, it frequents dense stands of Douglas fir and aspen. The mourning dove is the most widely distributed gamebird within the study area during the breeding and migration periods. During these seasons, it was observed in a variety of habitats, with the greater number of individuals noted in pinyon-juniper and greasewood/sagebrush vegetation types.

In the Tract C-a vicinity, a few surface ponds and intermittent streams create isolated islands of habitat for waterfowl and shorebirds. Because surface water is restricted in distribution in northwestern Colorado, such habitat types have an unusually high ecological value in this region. Fourteen waterfowl and shorebird species were recorded within the Tract C-a vicinity. Although usage of the area by waterfowl and shorebirds is greater during late spring and summer than during fall, the overall waterbird population within the study area is small. The paucity of open water is undoubtedly a major limiting factor on the size of the resident and migratory waterfowl populations. The mallard, green-winged teal, blue-winged teal, killdeer, and common snipe were the most common waterfowl and shorebirds utilizing surface waters of the area.

The distribution of raptors observed during the aerial surveys demonstrated a number of interesting trends. The majority of raptors were recorded within the eastern half of the study area, along the drainages. Frequently observed raptors were the raven, rough-legged hawk, and golden eagle. Aerial surveys were not conducive for sightings of small, low flying raptors such as accipiters and falcons. Thus, the few small, low-flying raptors recorded during aerial surveys were not a fair indication of the relative abundance of these birds of prey on the study area. Fourteen diurnal and four nocturnal raptors were encountered between October, 1974 and October, 1975. The red-tailed hawk was frequently observed during all times of the year except during the late winter sampling period. The rough-legged hawk was the most common wintering raptor. This species breeds on the arctic tundra, so it was not present during summer. The golden eagle was observed frequently throughout the year. A greater number of golden eagle observations occurred during winter than during other seasons, suggestive of a winter concentration in the Piceance Basin. The

marsh hawk and American kestrel were common nesters and a few individuals were recorded most frequently throughout the year; it was present in all vegetation types within the study area. Other diurnal raptors observed less frequently were the turkey vulture, goshawk, sharp-shinned hawk, Cooper's hawk, Swainson's hawk, bald eagle, prairie falcon, merlin, and peregrine falcon.

The night owl surveys demonstrated the presence of four nocturnal raptor species, the pygmy owl, short-eared owl, screech owl, and great horned owl. The latter is the most common owl within the study area and was encountered in a variety of vegetation types.

Thirty-one active nest sites were located on the study area during the raptor nesting survey. Six red-tailed hawk, seven American kestrel, seven great horned owl, three common raven, three marsh hawk, two Cooper's hawk, two golden eagle, and one goshawk nests were encountered.

The year's census data indicate that most species encountered in the area of investigation are those expected to be present based on published information from northwestern Colorado and northeastern Utah (Bailey and Niedrach, 1965; Hendee, 1929; Twomey, 1942).

Several unusual species were observed. Most have been recorded previously in northwestern Colorado, but only as unusual occurrences.

> White-faced Ibis - Two individuals were observed in bottomland areas where seepages or annual streams occur. The first bird, observed on April 17, was foraging along the stream bottom in Corral Gulch 1 km west of 84 Mesa Ranch. The second bird, observed on April 26, was observed near a spring seepage in Little Duck Creek. Both birds were photographed. The white-faced ibis, occurring in very small numbers, is probably a regular migrant in both spring and fall to northwestern Colorado. Twomey (1942) found this species to be a common spring migrant to the Uinta Basin area of Utah. Davis (1969) considers the bird to be a rare visitor to the western slope, while Bailey and Niedrach (1965) list white-faced ibis records only for Gunnison County,

Colorado. Martin, Baldwin, and Reed (1974) observed individual flocks of 8-15 and 42 birds at ponds in the vicinity of Hayden, Colorado, in early April and early May, 1973, respectively.

- Greater Sandhill Crane - Sandhill cranes were observed on 84 Mesa and along Piceance Creek during the spring and fall of 1975. A discussion of the status of this species in the study area may be found in section 7.3 (Threatened and Endangered Species).
- Sora - On June 6 and 11, 1975, soras were observed at the Stake Springs Draw pond. Davis (1969) described the sora as an uncommon summer resident of the cattail swamps in western Colorado.
- Long-billed Curlew - On June 2, 1975 a long-billed curlew was recorded in a flooded pasture along Ryan Gulch. This species is considered rare west of the Colorado Continental Divide (Bailey and Niedrach, 1965). Martin, et al. (1974) recorded one individual on agricultural fields near Craig during the summer of 1971.
- Short-eared Owl - Two individuals were encountered during the owl census conducted December 17, 1975. Davis (1969) classified this species as an uncommon winter visitor to open fields. The species was noted by Rockwell (1908) in the winter of 1904-05 in Mesa County. Felger (1910) observed a pair in Moffat County in April, 1924. Twomey (1942) reported that one short-eared owl was seen at the Ashley Creek marshes of northeastern Utah in late September, 1937.
- Red-eyed Vireo - Two red-eyed vireos were recorded in an aspen stand along Cathedral Bluffs during a qualitative survey. This species is a rare visitor to western Colorado (Bailey and Niedrach, 1965; Martin, et al., 1974). Its preferred nesting habitat in western United States appears to be the cottonwood-willow river bottom. The paucity of this vegetative type in the Piceance Basin is probably the major limiting factor on the basin's red-eyed vireo population.
- Bobolink - The bobolink, an unusual species for this area, was recorded once during June. Since the habitat of the bobolink is limited rather strictly in the intermountain area to western pasturelands, its distribution in Colorado seems to be spotty and it has not previously been recorded in the Piceance Basin. Although little or no cultivated land is found within the study area, the observed

bobolink was probably a wanderer from the agricultural lands along Piceance Creek.

- McCown's Longspur - This species was observed on Cathedral Bluffs in October and again in February. McCown's longspur is a local breeder in eastern Colorado but was not listed as occurring in western Colorado by either Davis (1969) or Bailey and Niedrach (1965).
- Chestnut-Collared Longspur - A single individual was recorded during a strip transect census through the upland meadow habitat during October, 1974 and two individuals were recorded within this transect during June, 1975. Bailey and Niedrach (1965) indicated this species is a local breeder in Weld County, eastern Colorado. They list only a single record of the chestnut-collared longspur for western Colorado.
- Snow Bunting - A flock of 32 snow buntings was observed on Cathedral Bluffs during February. A search of the literature on species recorded from western Colorado indicated that this sighting is probably the first record for this species in northwestern Colorado.

E. Winter Track Counts

1. Objectives - Once each winter, snow track counts are made to provide information on the relative use of different habitat types by certain big game, lagomorph, predator and small mammal species.

2. Methods

a. Data Collection - Transects 270 m (885.6 ft) in length are established along one line of stations of the small mammal live-trapping grids in each of the major vegetation types. Line A of the small grids and line F of the larger grids are used for this purpose. All existing tracks are obliterated from each transect at a known data and time, either by a new snowfall or by sweeping tracks from the transect, leaving a cleared path at least 1.2 m (4 ft) wide. No sooner than 22 hours after old tracks have been cleared new tracks are identified and the number of crossings of each track type counted and recorded, along with the date and time the transect is surveyed. Not more than 50 hours will elapse after the old tracks are cleared. Ideally, track counts are made in this way at least twice during each sampling period, but only those transects surveyed on the same day are used for later interpretation. Transects are also discounted if wind and new snow interfere with accurate identification and counting of tracks.

b. Data Analysis - In order to compensate for different exposure times on different transects, an index of relative abundance was calculated by the following derived formula:

$$I = \frac{24T}{E}$$

where:

I = Index of relative abundance

T = Total number of tracks, each species, each transect

E = Number of hours of exposure, each transect

24= Number of hours in a day

As this index represents the number of tracks observed per 24 hour period for a given transect, it provides a tool for determining the relative abundance of species in different vegetation types.

3. Data Summary - Winter track counts were made on eight transects in seven vegetation types between February 13 and February 21, 1975. Due to adverse weather conditions and inaccessible transect sites, certain days afforded incomplete results. The best results were obtained on February 16 and 19, when all eight transects were surveyed and snow and wind did not interfere. Therefore, the data from these two days will be used exclusively for interpretation.

Tracks of at least seven animal species (several were identified only to genus). were identified on the eight transects on February 16 and 19.

Mule deer tracks were encountered on four of the eight transects, with most occurring in a north-facing pinyon-juniper vegetation type. Cottontail tracks occurred on four transects and were most abundant in both greasewood-sage and south-facing pinyon-juniper. Only one chipmunk (Eutamias sp.) was recorded, that being in south-facing pinyon-juniper habitat. Mice and voles (Peromyscus sp., and Microtus sp.) occurred on four of the transects and in a variety of habitat types. Coyote (Canis latrans) tracks were recorded on four transects and were most abundant in the bottomland meadow. Two sets of bobcat (Lynx rufus) tracks were observed side by side in south-facing pinyon-juniper. Weasels (Mustela sp.) occurred in rabbitbrush and mixed brush vegetation types. The three transects above 7,200 ft (sagebrush, mixed brush, and upland meadow) had the lowest total numbers of track crossings.

The high track count of mule deer on Transect C would seem to indicate a preference for pinyon-juniper; however, none were encountered in Transect B, also pinyon-juniper. This extreme difference between track occurrences may be explained by differences between the two sites. Transect B is on a steep, south facing slope while Transect C is on a more gentle, north-facing slope. Near Transect B (~150 m) and running parallel to it was a heavily used road, while the road near Transect C was unplowed. See pages 3-7-645 through

3-7-647 of the Second Annual Report (RBOSP, 1976) for complete tabulated results of winter track count studies.

4. Discussion

Track count data show the greatest number of tracks were left by mule deer, cottontails and coyotes. Direct comparison of the numbers of tracks left by one species in comparison to those left by a different species may not yield valid conclusions about the relative abundance of the two. Track counts may be more accurately termed "use indices" since they are best used to indicate relative use of the different vegetation types by each species.

Adjusted track counts suggest that during the sample period mule deer favored the pinyon-juniper (north slope) vegetation type by a wide margin over all other types. Rabbitbrush, a bottomland site adjacent to pinyon-juniper (north slope), showed the second highest number of track crossings, a possible indication of nighttime foraging on bottomland shrubs.

The predominance of cottontail tracks on the pinyon-juniper (south slope) and greasewood/sagebrush transects, despite low coyote tracks, may be an indication that coyotes find bottomland meadow hunting more successful or that the single transect in each type sampled too small an area for too short a time to record the movements of wider-ranging animals such as coyotes.

The high adjusted track counts for coyotes in bottomland meadow indicated that prey abundance in that type, even though largely under the snow, has attracted coyotes to hunt the meadow extensively. Similarly, the high track count index for mule deer in north slope pinyon-juniper reflects their probable use of this stand for shelter during the sample period.

Comparisons between species in a given vegetation type are complicated by species' differences in behavior and foraging patterns. Mice and, especially, voles may travel under the snow surface, while the larger mammals must leave visible tracks if they move through an area. In addition, the larger mammals such as deer and coyotes might be expected to range farther than mice, voles, and cottontails which have a much more restricted range. Thus, the smaller

species might be expected to cross a given track count transect more frequently during their normal foraging within more restricted areas. An exception to this might be the short cycle, zig-zag hunting patterns of a coyote. December 1974 small mammal live-trapping data showing abundant mouse and vole populations in the bottomland meadow support the possibility that hunting coyotes accounted for the large number of coyote tracks recorded at that site.

Mule deer, cottontail, and coyote tracks were recorded more often than tracks of any other mammalian species. The majority of the mule deer tracks were recorded on the pinyon-juniper (north slope) site. Cottontail tracks were abundant on pinyon-juniper (south slope) and greasewood-sagebrush sites. Coyote tracks were most abundant on the bottomland meadow site.

F. Reptiles and Amphibians

1. Objectives - The purpose of the reptile and amphibian sampling program is to determine habitat preference, distribution and, when possible, abundance of species of reptiles and amphibians occurring on and near Tract C-a.

2. Methods - Line transect methods are employed to sample reptiles and amphibians in all major habitat types on and near Tract C-a. Ten transects, each approximately 1,000 m (3,820 ft) in length, are surveyed once during June and August, 1975 and 1976 by two observers walking far enough apart to preclude duplicate observations. Five transects are permanently located, one in each of the five major vegetation types (pinyon-juniper on north and south-facing slopes, sagebrush, greasewood/sagebrush, and mixed brush). Non-permanent transects are relocated during each sampling period to ensure that all vegetation types are sampled at least once during the two-year period. Species, numbers, microhabitat type, sex and age class (when possible), various environmental parameters and other data are recorded.

Information regarding nocturnally active amphibian species is gathered opportunistically by field personnel. Two nights during May and June, 1975 and 1976 are devoted to sampling potential amphibian breeding sites (ponds) on and near Tract C-a. Species, numbers, habitat description, and sex and age class are recorded.

The first individual of each species encountered in the area is killed by an injection of phenobarbital and prepared as a voucher specimen.

3. Data Summary

a. Line Transects - Herpetofauna line transect surveys were conducted twice during the past year (June and August, 1975). Five permanent transects located within the major vegetation types were flagged and surveyed during both sampling periods. In addition to these permanently located transects, non-permanent transects located within selected habitats were surveyed during each sampling period. Thus, data were collected from 15 locations, with five of these locations being sampled twice.

Because of equal sampling intensities at each location (two observers walking 1,000 m), results for each sampling site are directly comparable. It is important to note that adjustments were not made in the results to compensate for existing differences in relative detectability of lizards at different locations. Therefore, abundances indicated in open areas (pinyon-juniper) may be disproportionately higher than was indicated for areas with heavy underbrush (e.g., mixed brush), because lizards are easier to detect in open areas.

During both sampling periods, a total of five reptile species was encountered on nine out of 20 transect surveys. These five species were recorded at six different locations within three major vegetation types (pinyon-juniper, sagebrush, and riparian) at elevations ranging from 6,300 to 7,400 ft , and with varying slope aspects. Reptiles were not recorded on the remaining 11 transect surveys. The vegetation types surveyed in which reptiles were not observed included mixed brush (three surveys at elevations from 7,300 ft to 7,600 ft and on southeast and north-facing slopes), bottomland meadow (one survey at an elevation of 6,300 ft and flat), rabbitbrush (one survey at an elevation of 6,700 ft and flat), shadscale (one survey at an elevation of 6,400 ft and on south-facing slope), and upland meadow (one survey at an elevation of 8,000 ft and flat).

The greatest abundance of reptiles was observed on transects located in pinyon-juniper; 57 of the total 61 reptile encounters were recorded on transects in this vegetation type. The greatest diversity of reptile species was observed on a transect in the pinyon-juniper/sagebrush vegetation type (elevation 6,300 ft ; slope south-facing), where there were steep sandstone outcroppings (Transect 6-NP).

The most frequently encountered species on the herpetofauna transects (50 out of 61 total encounters) was the sagebrush lizard (Sceloperus graciosus). This is one of the widest ranging and most abundant lizard species in North America (Tinkle, 1973) and is known to be mostly ground-dwelling, occurring in open areas with scattered bushes (Stebbins, 1966). In the study area, the pinyon-juniper vegetation type seems to provide the preferred habitat of the sagebrush lizard, with open ground as well as scattered brushes and deadfall under which these lizards seek shelter. Sagebrush lizards were recorded on all but one of the seven surveys within pinyon-juniper stands. Abundance of this lizard species was greatest on Transect 6-NP where there were steep sandstone outcroppings as well as bushes and deadfall.

The short-horned lizard (Phrynosoma douglassi) is a wide-ranging ground-dwelling lizard that inhabits a variety of habitat types in western North America (Stebbins, 1954). This species was frequently encountered in the study area but nowhere appeared as abundant as the sagebrush lizard. Four short-horned lizards were recorded during three transect surveys in two vegetation types: pinyon-juniper (6,900 ft /north-facing slope) and sagebrush (7,300 ft /northwest-facing slope). Opportunistic sighting records have documented the presence of this species in mixed brush and upland meadow habitats as well. The short-horned lizard has also been observed on Cathedral Bluffs at an elevation of 8,400 ft.

Two eastern fence lizards (Sceloperus undulatus) and four tree lizards (Urosaurus ornatus) were recorded along Transect 6-NP surveyed in the pinyon-juniper vegetation type beneath steep south-facing sandstone outcroppings. The eastern fence lizard is similar in appearance to the sagebrush lizard with which it may coexist, but it remains ecologically distinct in its microhabitat selection, foraging strategies and diet preferences. The eastern fence lizard is more often found perched on elevated structures such as rocks than is the predominantly ground-dwelling sagebrush lizard (Turner, 1974). The tree lizard climbs more

frequently than either of the two Sceloperus species. Neither the tree lizard nor the eastern fence lizard were commonly observed within the study area.

The only snake species encountered in the study area during the past year was the western terrestrial garter snake (Thamnophis elegans). This species occurs in a wide variety of habitats, ranging from damp environments near water to dry areas far from water (Stebbins, 1966). The subspecies which occurs in the study area is commonly found in mesic environments near streams and ponds (Stebbins, 1954). During herpetofauna transect surveys, the western terrestrial garter snake was observed only once. This sighting was in August on a transect paralleling a perennial stream into which the snake retreated when approached. Opportunistic sightings (five to date) have documented this snake species in upland sagebrush far from water, as well as in bottomland habitats where there is nearby standing or running water. It is not a species that is commonly observed in the study area.

b. Amphibian Breeding Sites - Potential amphibian breeding sites were visited on two nights in May and on two nights in June, 1975. Three amphibian species were observed or heard calling at two locations: Stake Springs pond and a small impoundment in Corral Gulch.

The chorus frog (Pseudacris triseriata) is a small but vociferous frog that is commonly found during the breeding season in the vegetation beside shallow ponds and slow moving streams. This species was encountered at both impoundments surveyed, but no more than five individuals were ever heard calling at one time on any of the nights when the ponds were visited. A few Great Basin spadefoots (Scaphiopus intermontanus) were heard calling one night in May at the Stake Springs pond. This toad-like anuran is well adapted to arid regions, where it burrows into the ground during dry weather and emerges to breed in permanent or semi-permanent water following spring and summer rains (Stebbins, 1966). The tiger salamander (Ambystoma tigrinum) was observed both months in the Stake Springs pond, most often in its larval, rather than adult, stage. The tiger salamander is also a species that is tolerant to the stressful conditions of arid as well as cold regions, and may or may not remain in the larval stage

to breed.

Tabulated results of reptile and amphibian data are presented on pages 3-7-657 through 3-7-660 of the Second Annual Report (RBOSP, 1976).

4. Discussion - Five reptile species were encountered on 20 herpetofauna line transect surveys conducted during June and August, 1975. The sagebrush lizard appears to be the most abundant reptile species in the study area; 50 of these lizards were observed or captured on six surveys at four different pinyon-juniper locations. The other reptile species encountered, but in fewer numbers, were the eastern fence lizard, tree lizard, short-horned lizard and western terrestrial garter snake. Greatest abundances of lizards were observed on transects within the pinyon-juniper vegetation type.

High species diversity is characterized by a large number of species occurring in a given area in approximately equal numbers (Pianka, 1967). In the Piceance Basin in general, and in Tract C-a study areas in particular, the diversity of reptile species appears low in comparison to that observed in surrounding areas (Thorne Ecological Institute, 1973 and Smith, Maslin, and Brown, 1965). This may be because the spatial heterogeneity (microhabitat diversity), an important factor in determining lizard species diversity (Pianka, 1967) is low in the area. The microhabitat diversity appeared high on Transect 6-NP where there were abundant high rock crevices as well as low-lying bushes and deadfall. Correspondingly, there was the greatest abundance (22 encounters) and diversity (three species) of lizard species at this site in comparison to other surveys wherein there were no encounters (12 surveys), encounters with only one species (six surveys) or encounters with only two species (one survey). Habitats such as that found at Transect 6-NP are rare in the study area.

Three amphibian species, the chorus frog, Great Basin spadefoot, and tiger salamander were encountered at two breeding ponds during May and June, 1975. Tract C-a study area appears to have very few habitats suitable to breeding populations of amphibians, and abundance and species diversity for this group appears low in the few places where amphibians do occur. This is probably due

in part to the temperature extremes and arid conditions of the area.

G. Invertebrates

1. Objectives - The objectives of the terrestrial invertebrate investigations are to collect and identify the abundant invertebrates associated with the major vegetation types, and to qualitatively and quantitatively describe the invertebrates whose hosts are made up of the dominant plant species within these habitats. Data serve as a basis for determination of the role of invertebrates in the ecosystem and a basis for future comparative studies on Tract C-a and the surrounding area.

2. Methods

a. Data Collection - Field sampling was conducted at five sites during June, July and September of 1975. The sampling sites were selected so as to concentrate on the major vegetation types found in the area and are located near small mammal grids A, B, C, D, and 5. These five sites are (1) greasewood-sagebrush, (2) south-facing pinyon-juniper, (3) north-facing pinyon-juniper, (4) upland sagebrush, and (5) mixed brush.

Various field sampling techniques are employed to capture invertebrates in different microhabitats at each sampling station, including pitfall, Malaise trap, sweeping, beating, litter D-Vac, and trap D-Vac sampling systems. A detailed description of all methodology used in invertebrate sampling is presented on pages 3-7-661 through 3-7-665 of the Second Annual Report (RBOSP, 197

b. Data Analysis - A description of the methods and formulae used to analyze invertebrate data is presented on pages 3-7-665 through 3-7-669 of the Second Annual Report (RBOSP, 1976).

3. Data Summary - For a complete discussion of invertebrate data see pages 3-7-669 through 3-7-724 in the Second Annual Report (RBOSP, 1976). For complete tabulated results of invertebrate data, refer to pages 3-7-744 through 3-7-871

of the Second Annual Report (RBOSP, 1976). Figures presented in this section are not absolute . See the Second Annual Report (RBOSP, 1976).

4. Discussion - Several different methods were used to sample invertebrates at five vegetation types in June, July, and September of 1975. In each of the vegetation types (greasewood-sagebrush, south slope pinyon-juniper, north slope pinyon-juniper, sagebrush, and mixed brush) samples were taken by pitfall, litter D-Vac, herbaceous sweep, and Malaise trap methods. Trap D-Vac samples were also taken from one or more of the dominant shrub species at each site. In greasewood-sagebrush and pinyon-juniper on north and south slopes, aerial sweeps and beating samples were also taken.

The following discussion will establish which invertebrate groups are numerically important within each vegetation type. Importance is based on a group's potential for influencing the health or biomass production of the dominant vegetation species. Groups peculiar to a specific habitat type and groups which are important in controlling invertebrate population fluctuations within each of the vegetation types will also be discussed.

Seasonal population trends of the important invertebrate groups and the possible effects of abiotic factors on these trends shall be presented when recognized. Comparisons of invertebrate groups within vegetatively similar sites and of the important aspects of invertebrate ecology over all sites will be emphasized.

The ground dwelling fauna in greasewood-sagebrush contained one order, Phalangida, which was captured in abundance at this site only. All of the captures were in pitfalls, indicating that the species of this order are probably not true litter dwellers, but were captured on the ground while searching for food or water. In order for this group to be active, there must be a continual source of free water for drinking (Savory, 1962). This water source was probably available at the greasewood-sagebrush site in June as a large number of Phalangida were captured at that time. In later sampling periods they were not captured frequently, leading to the assumption that their activity was limited by the lack of available free water. The assumption that free water was less frequent in July and September was substantiated by daily visual observations of the amount

of moisture in the pitfall cups. In June the presence of moisture in the cups was apparent nearly every day while in July it occurred only twice in the ten day period. In September, brief showers occurred frequently; however, the cool night temperatures probably precluded most nocturnal activity by Phalangida, and by early morning the vegetation and pitfall cups were already dry.

Mites (Acari) were also abundant in samples from greasewood/sagebrush, with large increases in captures as the season progressed. Most of the mite captures were hard-bodied Orbatid mites whose tolerance of extreme heat and dessication varies with the species (Butcher, Snider and Snider, 1971). It appears that the species found in this habitat are relatively tolerant to heat and dessication and can survive and reproduce under conditions of decreasing soil moisture. If in fact soil moisture was reduced over the season, then competition for food within the litter layer may also have decreased over the season as a result of reductions in numbers of other litter inhabiting groups, such as Collembola, which require moisture for feeding (Ford, 1937). This may be one of the factors contributing to the substantial increase in Acari captures over the sampling season. One other order, Psocoptera, was the only other order of ground dwellers which was abundant only in the greasewood-sagebrush habitat. Psocoptera probably avoided the presumed dry conditions by limiting their activities to the litter where they were captured in abundance in September. During July sampling, however, they were captured in large numbers in pitfalls.

The invertebrate fauna which inhabited the vegetation in greasewood-sagebrush can be divided into two groups based on whether they were found on the dominant shrub species or on the herbaceous vegetation.

Two families captured from the herbaceous vegetation appeared to be of importance due to their high total captures. In July, Chloropidae made up the bulk of the sweep sample. It is possible that this family, which was abundant at the greasewood-sagebrush site only, was the major herbivore group feeding on rye grass. The larvae of this family feed in the culms of grasses, and can reduce the production of grass species and the formation of flowering heads, thereby reducing seed production (Sabrosky, 1936; Blocker, 1969).

September sweep samples were dominated by a species of seed bug (Lygaeidae). It is suspected that the abundance of this group was also related to the large amounts of rye grass found in the understory of the greasewood-sagebrush site. Prior to the September sampling period, the nymphs of this family were probably feeding on the seeds of rye grass. The appearance of the adult stage coincides with drying up of the seeds when the grains no longer provide a succulent source of food. It appears that the sample was taken as the adults prepared to migrate to other sources of food, or find suitable places for overwintering.

Sampling of the two dominant shrub species in the greasewood-sagebrush habitat, sagebrush and rabbitbrush, revealed that total invertebrate captures were more abundant from these plant species than from shrub species sampled in other vegetation types. In samples from rabbitbrush, three herbivore taxa were common during different sampling periods. Thysanoptera, Anthicidae, and Cleridae were all found on the flowering heads of the plants sampled. Thysanoptera and Anthicidae are feeders on flower parts, and their abundance could have an effect on seed production. Both are known pests of range plants in grassland areas (Blocker, 1969; Brues, 1946). Cleridae was also considered a herbivore, although most members of the family are predators. The family is not known as a pest, although visual observations indicated that they were present in large numbers in the flowering heads of rabbitbrush in July. If they were feeding on flower parts, they could have a substantial effect on seed production.

Samples from sagebrush revealed a number of herbivorous families which were abundant throughout the season. Aphididae was probably the most important of these families in terms of the effects of their feeding on sagebrush. This family had large total captures in July and September, with the same species group abundant in each period. Their relative abundance later in the season is characteristic of aphid populations which reproduce in large numbers with several to many generations per season (Borror and DeLong, 1971). The presence and abundance of aphids may be the reason for relatively large numbers of lady-bird beetles (Coccinellidae) in the captures. This group is well known as predators of aphids although members of the family feed on many other insects as well (Borror and DeLong, 1971). Coccinellidae was only part of an abundant

predator fauna captured at this site.

Of the fauna captured in Malaise traps in greasewood-sagebrush, two families, Cecidomyiidae (gall midges) and Anthomyiidae, were very abundant and were probably the most significant insect groups in terms of their effect on the vegetation in the greasewood-sagebrush habitat. Many of the gall midges are considered pests because of their means of reproduction, which involves oviposition into the tissue of the plant host species and results in gall formation. Formation of these galls can cause disruption of normal plant growth and, in some cases, death of the plant tissue past the point of gall formation. Many plant species, including sagebrush, are hosts for a variety of gall makers, and in some instances this has led to weakening or death of the plants involved (Felt, 1965).

Several species groups of Anthomyiidae were abundant in July and September at all sites. Although little is known of their life histories, they must be considered important because of their large numbers. Anthomyiidae larvae have a variety of feeding habits including herbivore and dung feeding. Based on morphological characteristics, the groups sampled were not herbivores as larvae, but dung feeders. If this is the case, then this group probably plays an important role in nutrient recycling in the study area by breaking down detritus.

A group of wasp families with parasitoid larvae was captured in all strata at the greasewood-sagebrush site. There was a variety of species groups present in all samples throughout the season, with relatively large total numbers in most cases. The value of this group is well known in agriculture because of attempts to use certain species as a form of biological control of economic pest insects (Borror and DeLong, 1971). In a natural habitat these groups are beneficial in providing a source of control for rapid increases in populations of many groups of herbivorous insects. The host specificity of these parasitic wasp larvae (Borror and DeLong, 1971) combined with the fact that a wide diversity of parasitic wasp families and species groups exists in the study area indicates that this group may exert a considerable influence on the populations of a wide variety of herbivorous insects.

Dominant orders in the ground-dwelling fauna of the south slope/pinyon-juniper habitat were Collembola and Acari. In June, Collembola were captured in large numbers in pitfalls, but were absent from litter samples. Collembola require a moist environment to escape dessication and, more importantly, for feeding (Ford, 1937), indicating that moisture levels on the ground surface were probably high in June at some point during the day. Pitfall captures of Collembola probably occurred at night when cool temperatures and higher humidities existed. During the day, Collembola must retreat to protected microhabitats where humidities remain high, and it would seem that these conditions would exist in the thick litter layers under pinyon and juniper trees.

In July, Collembola were not collected in pitfalls but were abundant in litter. During this period moisture was probably not sufficient on the ground surface for Collembola to feed, and as a result they were found only in the litter. In contrast, Acari were not captured in large numbers until July and August, when they were the most abundant invertebrates. This increase in mites over the season was characteristic of all sites and was interpreted in discussions of trends in Acari captures for the greasewood-sagebrush site. It appears that the same reasoning for the existance of these trends applied to the Acari populations at this south slope pinyon-juniper site. The relatively low numbers of mites in June might be a result of the fact that most mite species have a relatively narrow range of temperatures in which they are active (Butcher, et al., 1971). During June,soil temperatures were quite low for most of the day reaching 15^{O}C only for short periods. In July, soil temperatures usually reached 15^{O}C by the time the first readings were taken in the morning. It is suspected that with the increase in length of time in which higher soil temperatures occur during the day, Acari populations were more active and increases in the population occurred.

The type of litter sampled also had a bearing on the numbers of invertebrates captured in all sample periods. Samples from litter under pinyon pine contained the majority of the captures in July, while juniper litter samples for the same sample period contained few invertebrates, none of which were Collembola. As the litter layer under both tree species was thick and somewhat moist, it is

possible that the juniper litter itself inhibited insect colonization to some degree. The presence of phenols in the tissue of juniper trees is known to prevent many herbaceous insects from attacking the foliage of juniper (Personal communication, T.O. Thatcher, 1975, Colorado State University), and this may also be the reason that the juniper litter was relatively free of insects.

Scorpions (Scorpionida) were found exclusively in the ground-dwelling fauna of south slope/pinyon-juniper habitat. Three individuals were captured over the summer within the pitfall grid boundaries, resulting in a density of 0.03 scorpions per m^2, a relatively high density for this large, mobile predator group. Air and soil temperatures were highest at this site relative to other sites throughout the sampling season, and this may be the reason for their presence at this site where the most xeric conditions existed.

Ants were captured in relatively large numbers at this site in July and September pitfall samples. They were observed actively moving about in the grid in the early morning but had disappeared by mid-day. This demonstrates a behavioral adaptation which is widespread in this family. The ants react to high temperatures by foraging earlier or later in the day when it is cooler.

Low herbaceous sweep sample totals reflect the sparse ground layer vegetation in the south slope/pinyon-juniper habitat. The dominant group as the season progressed was Aphididae, which had relatively large total captures in September. Ants were also common in all periods and in September were observed tending aphids on nearly every Leptodactylon sp. plant inspected in the vicinity of the grid.

Results of sampling shadscale revealed this plant species had the least number of associated herbivorous insects throughout the season. The relative thickness and hardness of the leaves as well as high salt concentration in the plant tissue may be a factor in the reduced numbers and variety of herbivorous insects on shadscale relative to other plant species sampled. In June, a group of Lepidoptera larvae in the superfamily Tortricoidea were abundant, presumably feeding on the foliage. By July they were no longer present, and it is suspected

that they had moved to the litter for pupation and later emerged as adults. This may in part explain the large number of adult moths present in July Malaise trap samples.

Scale insects were also abundant in June and September, but absent in July. The immature life-stage in which this group was captured was readily removed from the plants by vacuuming. The adult females, however, are stationary and fixed to the plant branches, and cannot be readily removed which may explain why no scale insects were captured in July.

Chironomidae was the most abundant group collected in samples from shadscale in July. It appeared as though adult Chironomidae were attracted to shadscale by a concentrated plant sap produced by the plant in response to moisture stress.

It is possible that this substance may have been of some nutritional value to the adult Chironomidae. Other shrub species sampled in the same vicinity as the shadscale did not harbor Chironomidae in large numbers.

Samples from pinyon pine contained few invertebrates in June, but in July and September a large number of Miridae was collected. This family feeds primarily on plant sap and is not always host plant species-specific (Borror and DeLong, 1971); however, their abundance in pinyon pine indicated that they may have been feeding on the foliage. Keen (1952) lists no Miridae species as economically important pests of pinyon pine.

Samples from juniper were dominated numerically by what appeared to be the same species group of Miridae captured on pinyon pine. This group was present throughout the sampling season.

Active flying groups captured in the south slope/pinyon-juniper habitat were dominated numerically by adult moths, Cecidomyiidae, and Anthomyiidae. All are herbivores or saprovores, either as larvae or adults, and where their numbers are large they can have serious effects on the vegetation upon which they feed.

The remaining group taken in abundance at the south slope/pinyon-juniper site was a species group of Scarabaeidae. Larvae of this family have a variety of feeding habits including herbivore and dung feeding.

Ground-dwelling invertebrates in the north slope/pinyon-juniper habitat exhibited many of the same characteristics as those captured in the south slope/pinyon-juniper habitat. In June, Collembola were abundant in pitfalls and absent in litter samples. Possible explanations were presented in the preceding discussion of the ground-dwelling fauna at the south slope/pinyon-juniper habitat. In July, however, results for the two pinyon-juniper sites differed in that Collembol were present in both pitfall and litter samples at the north slope/pinyon-juniper site. Collembola presence in pitfalls may be an indication that some moisture was available on the surface to prevent dessication and facilitate feeding.

Increased tree cover and less direct sunlight at the north-slope/pinyon-juniper site relative to the south slope site may have been partially responsible for this condition. In September, Collembola were present only in the litter samples and had substantially decreased in numbers.

It appears, then, that Collembola populations were actively feeding and reproducin for longer periods of time during the summer in the north slope/pinyon-juniper habitat than in the south slope habitat, therefore increasing consumption of dead plant material in the former habitat due to the longer time period of active feeding. Less obvious is the possibility that Collembola feeding on fungal hyphae could keep the fungi at maximum production, thereby indirectly increasing the amount of dead plant matter broken down (Christiansen, 1964).

Acari captures in the north slope/pinyon-juniper habitat exhibited the same trends in total numbers (for pitfall and litter D-Vac samples) as Acari population at the south slope/pinyon-juniper site. Suggested explanations already presented in the discussion of trends in Acari populations in the greasewood-sagebrush habitat are applicable to the Acari fauna at this site.

Low capture totals in sweep samples from the ground layer vegetation at the north slope/pinyon-juniper site were indicative of the small amount of vegetation in the understory. Only one group of herbivores, Psyllidae, was abundant in any of the sampling periods.

Visual observations of pinyon pine in the north slope/pinyon-juniper habitat indicated that ants were actively foraging in the foliage of most trees surveyed in June. Sweep and beating sample results supported this observation in that ants were the abundant group captured in June samples. No likely prey species or aphid populations were present in the samples at that time, however, indicating that the ants were probably feeding on vegetation rather than aphid waste products at that time. Ants observed in columns moving down the trees were not carrying visible food particles, leading to the conclusion that they were probably feeding on plant sap. In July, the Miridae found in pinyon pine in the south slope/pinyon-juniper habitat were also abundant in pinyon pine at the north slope/pinyon-juniper site. In addition, a few Aphididae were captured which indicated the beginning of a buildup in population of this group, members of this family are well known as economic pests on a variety of agricultural and rangeland plants. Aphids can also be economic pests of most tree species including the pines (Keen, 1952), although evidence of tree death due to Aphididae attack is an uncommon occurrance.

Samples from juniper foliage contained only one abundant herbivore group, the Miridae, which was also taken in large numbers from juniper in the south slope/ pinyon-juniper habitat.

A comparison of results for pinyon and juniper at both of the sites where the two species of trees are dominant indicated that overall there were more species groups of herbivores captured from foliage of pinyon than from juniper. It is possible that this was a result of the phenols present in juniper as discussed previously for litter samples at the north slope/pinyon-juniper habitat.

June Malaise trap results for the north slope/pinyon-juniper habitat revealed relatively large numbers of dipterans, including members of the family

Cecidomyiidae. The effect of this family on vegetation was discussed previously.

Two other families which contained relatively large total captures in June were Sciaridae and Mycetophilidae, families whose larvae are fungus feeders. The thick litter layer under pinyon pine contained large amounts of fungae hyphae, and it is possible that these families developed and emerged from this microhabitat. The remaining abundant group included two families of bees, Apidae and Andrenidae. These two families are members of the superfamily of bees which are important as pollinators in nearly any vegetation type. Their presence in this north slope/pinyon-juniper vegetation type, where the understory contained few insect-pollinated plant species, was unusual in view of the fact that they collect nectar and pollen. It is possible that the abundance of dead trees in this habitat offered the best choice of nest locations where a colony of bees could establish itself and still be within flying distance of areas such as sagebrush and rabbitbrush which provide a greater diversity of food plants. Reaching areas where food sources were more abundant would not be difficult for members of these families, which are known to range up to three miles in normal daily foraging activity (Dadant et al., 1975).

Most of the abundant groups found on sagebrush at the greasewood-sagebrush site were not present in trap D-Vac samples from sagebrush in the pinyon-juniper habitat. The plants sampled were in most cases relatively free of attack by herbivorous insects. One exception was a species group of Curculionidae which was found in relatively large numbers during all sampling periods. Most of the species in this family are monophagous or limited to a few plant hosts (Arnett, 1973), and in many cases larval development occurs within the stems of the plant. However, the larvae and adults do not always feed on the same plant species. The relatively low numbers of captures per plant may indicate that the damage to sagebrush is not substantial, although if the larvae were feeding within the stems, cumulative damage over several seasons could result.

The last group which showed potential for herbivorous damage of sage at this site was a species of immature scale (superfamily Coccoidea). On one plant

sampled in September, over 140 individuals -- a relative large number for a single plant -- were captured. The damage potential for this group is well documented for many herbaceous plant species (Borror and DeLong, 1971).

Death of plants caused by scale insect attack is not uncommon. Most damage is usually caused by a general weakening of the plant over a number of seasons.

When all sampling types used at the north slope/pinyon-juniper habitat over the season are considered, two groups appear to be the most important in terms of numerical abundance, diversity and distribution in the various strata. Ants are found in all types of samples and were considered the single most dominant of all families identified. Parasitic wasps were the other dominant group. This group is probably important in controlling the populations of many types of herbivorous insects as previously discussed.

The sagebrush habitat contained the largest captures of ground-dwelling fauna in June of any habitat type sampled. The majority of the specimens taken were in one species group of Collembola, which was captured in both pitfall and litter samples. Litter layers at this site were probably the least conducive to large population buildups of Collembola than at any of the other sites because the litter layer was generally shallow and found only at the bases of sagebrush plants. Physical factors which are conducive to surface activity of Collembola were previously discussed.

In July, Collembola were again numerous in pitfall samples but almost absent from litter samples. A favorable moisture supply again probably allowed for surface activity of this group; however, they probably retreated into the soil during harsher daytime periods of low humidity and high temperatures. It is possible that because of shallow litter layer, little shelter and humidity was afforded this group. Therefore, they may have been forced to seek shelter in more favorable microhabitats such as under rocks, and at the bases of relatively large shrubs and grass clumps.

Pitfall traps captured large numbers of ants in nearly all sampling periods. In June alone, over 500 ants were captured in the grid, which was a relatively large number foraging in an area of 100 m^2. This family can have a substantial effect on the vegetation of an area, particularly if they are existing as herbivores. In this role, which is common in many species during the spring, they gather seeds and crop young plants for food. Although western harvester ants were not included in the captures, their ability as seed gatherers and plant harvesters as reported in the literature is worth mentioning to give some idea of efficiency of members of this family in depleting the vegetation to obtain food. Rogers (1972) found that three medium-sized colonies could remove nearly 20 pounds of seeds per acre over a period of a year. In another study, Clark and Comanor (1975) determined that plant removal from around mounds in Nevada amounted to cutting of over 150 million plants per hectare per year.

Capture totals of invertebrates taken in herbaceous sweep samples were very low in all periods in view of the apparent abundance of grasses and forbs observed in the sagebrush habitat. No groups were numerically abundant in any period, and capture totals were relatively low compared to other sites in two of the three periods.

Samples from sagebrush in the sagebrush habitat contained relatively few herbivores or captures of any kind in nearly all sample periods. The numerically dominant group was the same species group of Curculionidae found on sagebrush at the north slope pinyon-juniper site. The potential effects of this group on sagebrush plants was discussed previously.

Malaise trap results were nearly identical to those of other habitats in terms of abundant groups, total numbers and seasonal trends of the fauna. Abundant groups during one or more sampling periods included Cecidomyiidae, adult moths, and Anthomyiidae. Chironomidae were abundant in June, although there is no permanent water source in the immediate vicinity of this site. Members of the family are weak flyers and depend on wind for dispersal, which probably is the means by which they arrived at the sagebrush habitat.

Parasitic wasps were the most diverse group of insects captured by all sampling techniques other than those designed for ground-dwelling invertebrates. They

are important in that they control the populations of many insect groups, particularly herbivores as previously discussed.

Ground-dwelling invertebrate captures in the mixed brush habitat were relatively low in June compared to other habitats, probably because Collembola were not as numerous here as they were in most of the other habitats. This is puzzling in view of the deep litter available at this site which appeared to be ideal habitat for Collembola populations. The relatively low numbers of Collembola appearing in litter samples were approximately equal in numbers for all sampling periods, an indication that moisture conditions were adequate for Collembola populations to exist throughout the season.

Ants were the numerically dominant group in pitfall samples in all sampling periods, and were relatively abundant in June and July litter samples at the mixed brush site.

The ground-dwelling fauna was diverse at the mixed brush site, with a variety of groups captured in all periods in both litter and pitfall samples.

Sweeps from vegetation other than the dominant shrub species contain the largest number of invertebrates in July and September of any habitat sampled. In both sampling periods, Aphididae was by far the most numerous family captured, totaling over 140 individuals in July and 1,300 in September. Visual observation of the vegetation in September revealed that the few rabbitbrush plants in the habitat were covered with Aphididae. The Aphididae appeared to be of the same species group, therefore it is possible that all came from the rabbitbrush plants sampled in the herbaceous sweep samples. If this is the case, such a large number of Aphididae on so few rabbitbrush plants could have an adverse effect on the rabbitbrush by removal of plant sap.

Samples from serviceberry in June and July did not contain insects in sufficient numbers to indicate possible plant damage by herbivorous insects. In September, total captures increased substantially with most of these being herbivores in the orders Hemiptera and Homoptera. Visual observation of the plants in September indicated that most of the foliage had dried up, and as a result it was difficult to explain the increases in the fauna from the earlier sampling periods.

Samples taken from snowberry were similar in composition to those taken from serviceberry. None of the herbivore groups present were abundant enough to cause widespread plant damage. The September snowberry fauna consisted primarily of Sminthuridae and Thysanoptera. In view of the observation that foliage of snowberry was nearly dry, it is possible that the fauna was actually present in litter under the plants preparing for the change in seasons, since both groups over-winter in the litter in the adult stage.

In Malaise trap samples, two groups, Chironomidae and adult moths, were abundant in all sampling periods. Chironomidae were very abundant in June, which appeared to be the result of large emergences from the nearby creek. This was consistant with Malaise results from other sites where Chironomidae were also the most abundant group captured in June. This family also had large total captures in July and September. This is consistant with the literature which shows that many species of Chironomidae have large peaks early in the season with continued smaller peaks throughout the warm months (Judd, 1962).

Adult moths were most abundant in July and also very common in June and September. As stated in the discussion of results for the south slope/pinyon-juniper habitat, the large number of adult moths in July was probably the result of pupation of larvae present in the early sampling period and subsequent emergence of adults. The presence of relatively large numbers in June indicated that groups captured probably over-wintered as larvae and began the transformation to the adult stage in June after temperatures increased to the point where overall insect activity began.

Lonchaeidae was one of the families found exclusively in the mixed brush habitat. Most of the species in this family occur chiefly in moist or shady places, and the larvae are secondary invaders of diseased or injured plant tissue (Borror and DeLong, 1971). Their abundance in June and July samples was indicative that some portion of the vegetation had been damaged in some manner. Vegetation sampling results from mixed brush stands did not indicate any apparent widespread damage to a particular plant species nor any widespread damage to all of the plants within a mixed brush stand. Possible sources of damage which

could have provided the source of larval food may have been browsing by horses in the winter or crushing of the foliage by cattle which are abundant in the area during the summer.

The presence of numerous cattle at the site may also have been the reason for the relative abundance of Sepsidae in the Malaise trap samples. The larvae live in excrement and the adults are often numerous near the excrement (Borror and Delong, 1971).

Anthomyiidae was the most abundant family in July and September samples as at other sites. Their feeding habits were unknown, but their abundance makes them an important group in some aspect of the food web at this site as well as at all other sites.

Total captures of invertebrates over the summer were greatest in the greasewood-sagebrush and sagebrush habitats. Major contributions to these totals came from Malaise trap samples in the greasewood-sagebrush habitat due primarily to large captures of Chironomidae and Anthomyiidae.

The ground-dwelling fauna captured in pitfalls was the most significant factor contributing to the overall invertebrate abundance in the sagebrush habitat. Large numbers of Collembola and Formicidae were responsible for most of this total. The mixed brush site also contained relatively large numbers of invertebrates, primarily due to high capture totals for herbaceous sweep samples. In both of the pinyon-juniper habitats, captures of ground-dwelling invertebrates and active flying insects were relatively high; however, samples from dominant shrubs and trees and herbaceous sweep samples were low in total captures. Low total captures in herbaceous sweep samples from the understory vegetation reflect the small amount of vegetation present.

Of the shrub species sampled, shadscale from the south slope/pinyon-juniper site had the least number and variety of associated herbivorous insects. Rabbitbrush and sagebrush from the greasewood-sagebrush site supported the largest number of invertebrates. By contrast, sagebrush samples from north slope/pinyon-juniper

and sagebrush habitats did not support the variety of invertebrates found on sagebrush in the greasewood-sagebrush habitat.

Seasonal trends in captures of the fauna in the various strata of each habitat indicate that peak populations occurred in July at all sites. Numbers of invertebrates in Malaise trap samples did not peak in July, however, but demonstrated the highest total captures in June and the lowest in September. Much of the reduction in captures from June to July at each site was due to the reduction in the number of Chironomidae which emerged in large numbers from nearby water sources in June.

The major orders of ground-dwelling invertebrates collected over all sample sites and all sample periods were Collembola and Acari. Collembola were very abundant at three sites, north and south slope/pinyon-juniper and the sagebrush habitat. Capture trends for the orders had a large peak in either June or July with substantial reductions or complete absence in September. Capture totals were related to the presence of adequate moisture needed to prevent dessication and facilitate feeding.

Acari were abundant at all sites, with large increases in captures as the season progressed. Moisture and heat effects which caused reductions in Collembola populations did not affect the most numerous group of mites, the hard-bodied Orbatids, because of their relative resistance to heat and moisture stress.

Most of the active flying insects were contributed by a variety of dipteran and hymenopteran families. A number of families were collected in large numbers at all sites including the two families which had the largest total captures, Anthomyiidae and Chironomidae. Anthomyiidae increased from relatively few captures at most sites in June to by far the largest total captures in July and September. Greasewood-sagebrush, sagebrush, and mixed brush habitats contributed most of the total Anthomyiidae captures. Cecidomyiidae were abundant in June at all sites, but varied in relative abundance by site in July and September.

Adult moths were abundant at all sites in July, and nearly all sites in September sampling periods. The major increase in total captures from June to July was the result of pupation of Lepidoptera larvae found most frequently in the June samples.

Phalangida and Psocoptera were abundant only at the greasewood-sagebrush site. The presence of large numbers of Phalangida in June only is related to the frequency of available free water. Two families were abundant only in samples from the greasewood-sagebrush habitat. Both are probably associated with rye grass, the dominant herbaceous species in the greasewood-sagebrush habitat. Chloropidae larvae are plant tissue feeders which inhabit the stems of the grasses and can cause reductions in seed production. The adults were abundant in July samples only. September samples contained large numbers of seed bug (Lygaeidae) which was abundant only in this period after rye grass seed formation was completed. This family is also known as a plant pest in certain situations.

South slope/pinyon-juniper was the only habitat which contained scorpions (Scorpionida) in the ground-dwelling fauna. Their presence at only this site is related to the overall higher ground temperatures that occur on this south-facing slope. Shadscale from the south slope/pinyon-juniper habitat was the only shrub species sampled upon which Chironomidae were suspected to be feeding, although this group was present and abundant at all sites. The Chironomidae were suspected to be feeding on liquids secreted by the plants. The south slope/pinyon-juniper habitat was also the only site in which ants were observed tending aphids.

At the north slope/pinyon-juniper site, no families of insects were captured that were not found at other sites; however, Apidae and Andrenidae were abundant at this site and not at the other sites. These two groups are important as pollinators, and it is suspected that their abundance in the north slope/pinyon-juniper habitat probably is related to the availability of nesting sites in dead trees.

No abundant families were found exclusively in the sagebrush habitat. The most

significant aspect of samples taken at this site was the presence of unusually large numbers of Collembola in June and July, although the litter present did not seem to be sufficient in terms of depth or abundance relative to the other four sites.

The mixed brush habitat produced two families of flies which were only abundant in this vegetation type. Lonchaeidae larvae feed on damaged plant material, and abundance of the adult stage may indicate that damage had occurred to some portion of the vegetation. Despite this apparent cause-effect relationship, no readily visible damage was observed in the vegetation. Probable causes of vegetation damage may have been browsing by horses or physical damage by cattle continuously moving back and forth through the site. The remaining abundant fly family, Sepsidae, was associated with large amounts of cattle dung at the site which probably provided the food source and substrate for larval development.

At all sites, the dominant shrub and tree species sampled had an associated complement of herbivorous insects which were contributed primarily by the orders Hemiptera and Homoptera. In most cases these species groups were different for each plant species because of the host species specificity of the families involved.

When all sites and strata within each site are considered, the dominant family overall was Formicidae. They were present and abundant in every type of sample. In most samples of ground dwelling invertebrates, Formicidae were either the most abundant group, or second in abundance to Collembola. They were found foraging on all of the shrub and tree species sampled and also were observed tending aphids on one species of herbaceous plant. Finally, Malaise trap results give an additional indication of their importance in that almost 500 reproductives were captured over the summer.

H. Domestic Livestock

1. Objectives - Numbers of livestock on the study area are being determined and areas of concentration are being estimated on a seasonal basis to help define the extent and type of grazing pressure exerted by domestic herbivores.

2. Methods

a. Aerial Censuses - Bimonthly aerial censuses are being used to determine the locations of domestic livestock within the area of investigation.

b. Utilization of Existing Information - Data regarding grazing history and tract use by domestic livestock were obtained from Bureau of Land Management (BLM) cattle allotment records. These records contain information on stocking rates, animal numbers, and season of utilization in the vicinity of Tract C-a.

3. Data Summary

a. Aerial Censuses - Domestic livestock censuses were conducted approximately every two months during the past year commencing with a November 8, 1974 aerial survey. On that day, 24 of 26 cattle observed on the tract were in the northeast corner of Tract C-a (section 34). Various sized groups of cattle were widely distributed over the study area, most heavily on 84 Mesa and southeast of the tract between Ryan Gulch and Black Sulphur Creek. One large group was observed on top of Cathedral Bluffs.

By December 30, 1974, no livestock were left on Cathedral Bluffs. Only ten cattle were seen on Tract C-a, and these were observed near the southern boundary. Small groups of cattle were scattered across the study area but over 90% were observed in the southeast sector, between Stake Springs Draw and Black Sulphur Creek.

On March 4, 1975, only two groups of cattle were observed on the study area. Four were seen on Little Duck Creek at the extreme northern border of the study area, and 47 cattle were concentrated on Black Sulphur Creek.

By April 14, 1975, the group on Little Duck Creek had grown to 26 head and 41 cattle were congregated in Ryan Gulch.

On June 26, observers noted no cattle on Tract C-a. A few small groups were seen northwest of the tract. Cattle were heavily distributed on 84 Mesa in the northeast sector of the study area, and were also observed east and southeast of Tract C-a. Thirty-six head were seen on top of Cathedral Bluffs near the Clyde Dillon Monument.

On August 18, most animals were observed to have moved to higher elevations along Cathedral Bluffs and ridges perpendicular to them. Only three small groups were seen that were not in the western 1/3 of the study area. For figures showing the distribution of cattle in the study area over all census periods, refer to pages 3-7-876 through 3-7-881 of the Second Annual Report (RBOSP, 1976).

Aerial observations were not conducted at frequent enough intervals to definitively assess the areal extent of spring and fall ranges.

Data regarding the degree of forage utilization in the various plant communities is available in Section 7.1-D.

b. Utilization of Existing Information - Three Bureau of Land Management grazing allotments exist in the vicinity of Tract C-a (Figure 3-7-1). The Reagle and Square S Allotments have been placed under allotment management plants (AMP). The BLM is presently preparing an allotment management plan for the Box Elder allotment. These allow the Bureau broader flexability in establishing stocking rates depending upon year to year range conditions. The allotments are described as follows:

- Square S Allotment - 64,050 A of BLM lands, 11,689 A of private lands for a total of 75,739 A. The grazing season is from May 5 through November 25. The BLM has estimated a carrying capacity of 5,896 AUM's, based on a 1941 Range Survey. The recent chaining of 4,500 A of pinyon-juniper was estimated to add 787 AUM's to that capacity.

An Allotment Management Plan was formulated and implemented by 1969, and was updated in 1972. Actual (licensed) stocking rates in the last five years were as follows:

1971	not available
1972	4,535 AUM's
1973	3,759 AUM's
1974	3,290 AUM's
1975	4,871 AUM's

- Box Elder Allotment - 26,071 A of BLM land, 2,210 A of DOW lands, and 1,970 A of private lands result in a total allotment of 30,251 A. The grazing season is from June 23 through October 8. The BLM has estimated a carrying capacity of 1,517 AUM's, based on a 1973 Range Survey. Actual (licensed) stocking rates for the period 1971-1975 were:

1971	1,344 AUM's
1972	1,344 AUM's
1973	1,344 AUM's
1974*	1,124 AUM's
1975	1,124 AUM's

- Reagle Allotment - 23,753 A of BLM lands and 2,190 A of private lands for a total of 25,943 A. The grazing season extends from May 3 to September 15. The BLM has estimated a carrying capacity of 2,318 AUM's, based on a 1941 Range Survey. Actual (licensed) use in the past five years has been:

1971	1,266 AUM's
1972	2,097 AUM's
1973	1,473 AUM's
1974	1,773 AUM's
1975	1,334 AUM's

Recent range improvements include a fencing project in 1971 and water developments in 1973 for enhancing management systems. An Allotment Management Plan was initiated in 1969, and implemented on the Reagle Allotment in 1971.

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*Rotation system for the benefit of deer implemented.

4. Discussion - Cattle distribution and dispersal in the area of Tract C-a are initially dictated by herding, but elevational and seasonal changes on the range then become the most important considerations. The cattle moved to higher elevational ranges in the spring as the snowpack receded and vegetation became green. In the fall, inclement weather conditions forced the cattle to return to lower elevation rangelands.

Salt stations in several observed instances were located at waterholes, which contributed to concentrating cattle there. Salt stations, for example, were found at the end of the road in Corral Gulch when the creek was running, and just off the road north of the pond in Stake Springs Gulch. Other salt stations were observed at convenient drop locations on Cathedral Bluffs. Forage was quickly depleted where salt was located near water, requiring cattle to range farther from the source of water/salt as the season progressed.

Toward the middle of summer, water availability became a more critical factor limiting livestock distribution. Water sources on Corral and Ryan Gulches dried up by mid-summer leaving Water and Spruce Gulches, Stake Springs, Cottonwood Spring, Maverick Spring, and Duck Creek as the only sources.

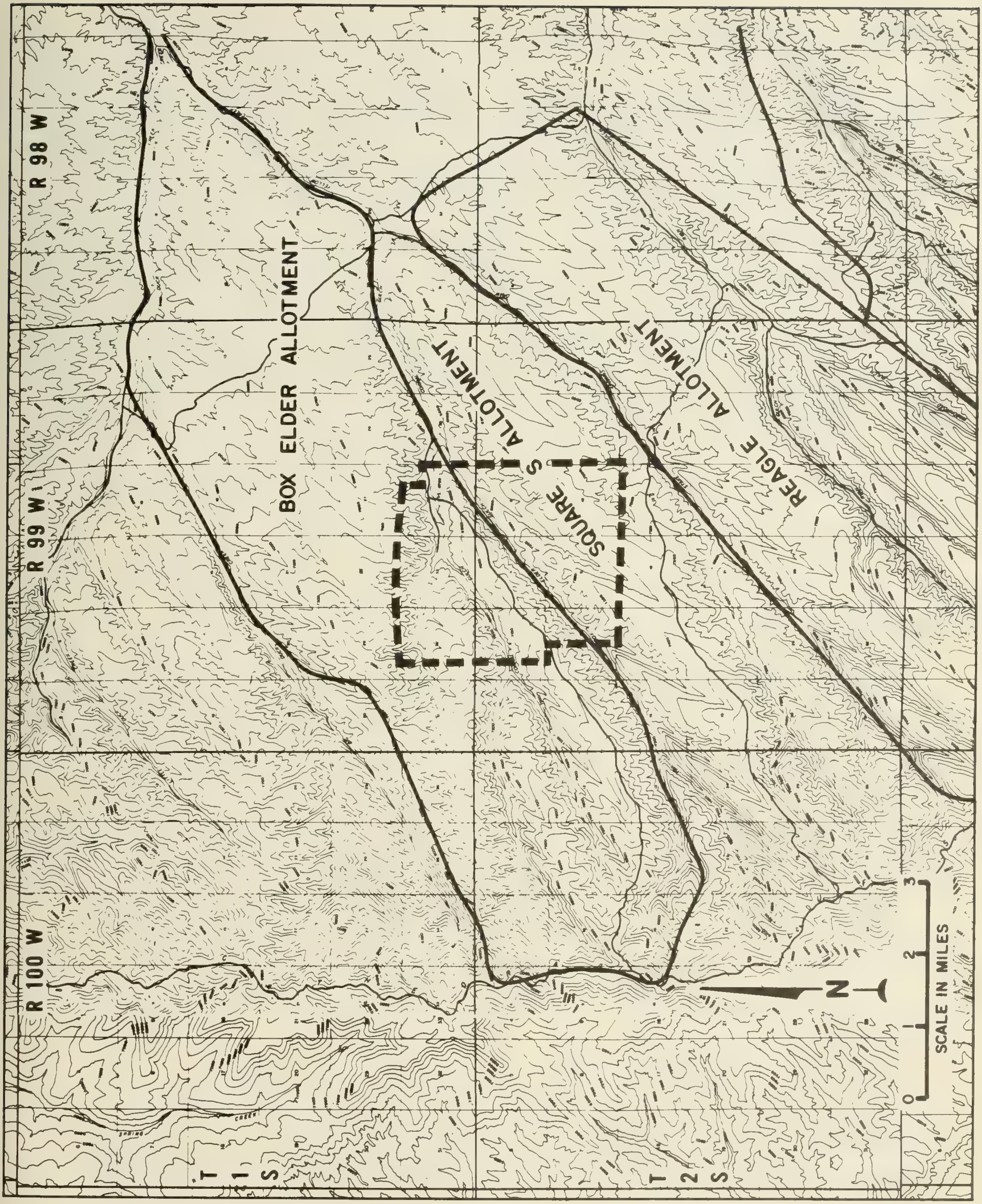

Figure 3-7-1
BLM GRAZING ALLOTMENTS

7.3 THREATENED AND ENDANGERED SPECIES

A. OBJECTIVES - Federal and state wildlife agencies and the Smithsonian Institution have compiled lists of plant and animal species which are "threatened," "rare," or "endangered." In determining the status of a species, the entire range of that species is considered. Confusion still exists regarding what constitutes a "threatened," "rare," or "endangered" species. An "endangered" species is in danger of extinction throughout all, or a significant portion of, its range; a "threatened" species is likely to become endangered within the foreseeable future throughout all, or a significant portion of its range; a "rare" species exists as a small population within its range (United States Department of the Interior, 1973).

If any of these species are present in the study area, they will be identified and their location and reliance on local habitats determined.

B. Methods

1. General Investigations - Throughout earlier sections of this and previous reports, specific quantitative and qualitative sampling techniques have been described which are to be performed within all major vegetation associations in the vicinity of Tract C-a to inventory and enumerate the species of plants and animals present. Cumulatively, these techniques should ascertain the presence of threatened, rare, or endangered species. Once discovered, special efforts may be directed at determining the distribution and habitat utilization of the species on and near Tract C-a. The greater sandhill crane, endangered as a nesting species in the state of Colorado, has been observed on 84 Mesa north of Tract C-a and has therefore been subjected to this closer scrutiny.

2. Greater Sandhill Crane Surveys - Between April 17-30, 1975, up to 30 greater sandhill cranes (Grus canadensis tabida) were observed displaying and foraging on 84 Mesa northeast of oil shale Tract C-a. The use of 84 Mesa

and contiguous areas by greater sandhill cranes had not been reported prior to these April investigations. Greater sandhill cranes nesting in northwestern Colorado concentrate their spring staging activities near Hayden and disperse to nesting areas approximately 40.2 km (25 mi.) away. It was considered that the greater sandhill cranes were utilizing 84 Mesa for staging and might nest in suitable areas near there, or continue north to Idaho, Wyoming or Montana. The population of greater sandhill cranes that nests within Colorado has been designated as "endangered" by the Colorado Division of Wildlife Colorado Wildlife Commission, 1973. This designation does not apply to populations stopping temporarily within Colorado during migration periods. A survey was conducted during June, 1975, to determine if greater sandhill cranes nest in portions of the Piceance Basin. A survey during September and October, 1975 was conducted to determine whether greater sandhill cranes utilized 84 Mesa and environs during their fall southward migration.

a. Spring Surveys - The spring aerial and ground surveys were conducted in Rio Blanco County and consisted of the following areas: (1) 84 Mesa and the adjacent Duck Creek valley; (2) Piceance Creek valley from Rio Blanco to the White River; (3) Douglas Creek valley from the confluence of its two main forks to the White River; and (4) the White River valley from 16.1 km (10 mi.) east of Rio Blanco Lake to 16.1 km (10 mi.) west of Douglàs Creek.

An initial aerial survey was conducted on June 6, 1975, to systematically map potential greater sandhill crane nesting areas; these potential areas were more closely scrutinized from the ground. Transects spaced at 1.61 km (1 mi.) intervals were flown at an indicated air speed of 145-161 km per hour (90-100 mph) and at an altitude of 61-76 m (200-250 ft.) above ground level.

Following the initial aerial survey, a thorough ground survey of 84 Mesa and the adjacent Duck Creek drainage was conducted between June 11-16. All locations of greater sandhill cranes sighted in earlier work were checked. Since free water is essential to cranes for nesting habitat (Walkinshaw, 1965), valleys were explored for water at 1.61 km (1 mi.) intervals or whenever

rough-winged swallows, which are common near water, were observed foraging above the valleys. When water was present, the length of the drainage was examined for cranes and/or their footprints.

The ground survey of the remaining potential nesting habitats was completed between June 26 and July 4. The vehicle was stopped approximately every 0.48 km (0.3 mi.), and the area was thoroughly scanned with 7 x 35 binoculars and/or a spotting scope. Areas that were inaccessible by truck or that afforded particularly good crane habitat were traversed on foot. Littlefield and Ryder (1968) described good greater sandhill crane breeding habitats as tracts having minimal disturbances, a feeding meadow, nesting cover, and nearby water. These criteria were used in designating greater sandhill crane breeding habitat in this study.

On June 30 at 0640, a final aerial survey was conducted to reexamine potential nesting sites for greater sandhill cranes and to determine where further ground survey efforts should be concentrated. Indicated air speed ranged from 129-145 km per hour (80-90 mph) at an altitude of 46-53 km (150-175 ft.) above ground. Air and light conditions were excellent, providing for good visibility. The portion of the White River within the study area was flown three times because it contained the best potential nesting habitat. Douglas Creek was flown twice and Piceance Creek once. The confluences of the major tributaries to the above stream courses were also recanvassed for location of possible nesting sites.

During the two ground surveys, residents of the study area were interviewed to determine whether they had observed cranes in the area. The interviewees were asked if they had seen any large birds in the area and, if so, to describe the birds. It was determined by inquiry whether the residents were possibly confusing greater sandhill cranes with great blue herons, the only other bird in the study area of comparable general appearance. Residents who were not initially familiar with the greater sandhill crane or did not describe it

properly were shown several photographs of the bird to determine if they then recognized it. Residents that were familiar with greater sandhill cranes were also shown pictures.

b. Fall Surveys - The fall survey area, located on 84 Mesa was restricted to those portions of the mesa dominated by big sagebrush. The topography of this xeric mesa varies from flat to slightly rolling.

The area was ground-surveyed four times. The initial survey, on horseback, commenced September 4, 1975. The remaining surveys occurred September 13-14, 1975, on horseback and foot; September 19-20, 1975, on foot; and September 30, 1975, on horseback and vehicle. Transects were spaced at intervals that would insure complete coverage of the area. The transect interval was reduced in the area where greater sandhill cranes were observed during April, 1975. The area was thoroughly scanned with 7 x 35 binoculars and/or a 20 x spotting scope.

On October 8, 1975, a flock of greater sandhill cranes was observed near the confluence of Piceance Creek and Ryan Gulch. Following that observation, a thorough ground survey of 84 Mesa and Piceance Creek by vehicle was conducted. Residents were interviewed to determine whether they had observed any cranes in the area. An aerial survey was conducted on October 9, 1975, and covered the following areas: (1) Piceance Creek valley from Rio Blanco to the White River; (2) Tract C-a; (3) 84 Mesa and nearby gulches; and (4) Yellow Creek to the White River. The survey was flown at an altitude of approximately 46 m (150 ft) above ground level and at an indicated air speed of 121-129 km per hour (75-80 mph). An additional aerial survey was conducted on October 22, 1975, and covered the same areas of the October 9, 1975 survey. This survey was flown at an altitude of approximately 61 m (200 ft) above ground level because of turbulence.

Two flocks of greater sandhill cranes were observed on 84 Mesa on October 25, 1975. Following that observation, a ground survey of 84 Mesa, Duck Creek, and Yellow Creek was conducted November 4 and 5. During the regular mule deer and raptor census flight of November 6, 1975, time was taken to survey 84 Mesa and environs for greater sandhill cranes.

c. Data Summary

1) General Investigations - One plant species, an endangered milkvetch (*Astragalus lutosus*, Smithsonian Institution, 1975) (observed off of Tract C-a), and two animal species, the endangered peregrine falcon (*Falco peregrinus anatum*) (United States Department of the Interior, 1974) and the endangered, if nesting in Colorado, greater sandhill crane (*Grus canadensis tabida*) (Colorado Wildlife Commission, 1973), have been observed in the study area to date. The prairie falcon, which was listed as threatened by the United States Department of the Interior (1974) but has recently been dropped from the list (United States Department of the Interior, 1975), is included here because of its status during the reporting year.

During the reporting year 1975, two specimens of the rare milkvetch were found growing on shale outcroppings on Cathedral Bluffs and Dead Horse Ridge. Two of the four peregrine falcons observed were on Tract C-a. One peregrine falcon was observed in Swizer Gulch in April, 1975; one on Wolf Ridge in June, 1975; one on Airplane Ridge in July, 1975; and one in Corral Gulch drainage in August, 1975. Seven observations of adult prairie falcons occurred on the study area: one at the confluence of Corral Gulch and Stake Springs Draw during December, 1974; one on Wolf Ridge in May, 1975; two on Cathedral Bluffs in June, 1975; one on Tract C-a in Corral Gulch in June, 1975; and two in Stake Springs Draw in July, 1975.

Because of their high mobility, it is not feasible to say exactly how many different individual peregrine or prairie falcons were observed. Also, the high mobility of these species and the low number of observations

preclude the designation of habitat preference for either species in the study area.

2. Greater Sandhill Crane Surveys

a. Spring Surveys - No greater sandhill cranes were observed in any of the areas examined by air or on the ground during the spring surveys. The White River valley, with its willow swamps and nearby grainfields, provided the best potential breeding habitat. Two other potentially appropriate nesting areas were located on Duck Creek and Big Duck Creek. Both areas provide year-round water. Cottonwoods are located at the potentially suitable breeding site near Big Duck Creek while dense aquatic vegetation and insects are prevalent at the site on Duck Creek. After air and ground survey, many of the smaller creeks were ruled out as providing suitable nesting sites because they did not meet one or more of the requirements for suitable nesting sites.

Conversations with area residents provided no evidence that greater sandhill cranse are nesting in the vicinity of 84 Mesa or elsewhere in the Piceance Basin. However, filed personnel reported observing a single greater sandhill crane flying near the junction of Piceance Road and the White River on June 26, 1975. Many residents described the great blue heron as a recurring visitor in their locality and did not recognize the photographs shown to them of greater sandhill cranes. Several residents reported that although they were familiar with the greater sandhill crane, they had not observed any in the vicinity. Some residents along the White River described seeing several to many cranes land in their fields or along the river during past migration periods, but these birds never remained for extended periods. One rancher on Piceance Creek reported that several cranes foraged along the creek during the high winds and rainy period of April, 1975. It appears that cranes have visited the White River and Piceance Creek in past years, but no resident knows of any having actually nested in the survey area.

b. Fall Surveys - Greater sandhill cranes were not observed during the the scheduled fall ground surveys. On October 8, 1975, a flock consisting of 13 adult and seven jueveni1e cranes was observed flying 0.8 km (0.5 mi) east of the confluence of Ryan Gulch and Piceance Creek. Conversations with local ranchers and Tract C-b personnel revealed that a flock of 19-20 greater sandhill cranes was observed on the Weidland Ranch on Pcieance Creek several days prior to the October 8th observation. The cranes observed by Tract C-b personnel and local ranchers may have been the same flock which was observed foraging along Pcieance Creek. All observations occurred in the same general area within a few days of each other, and approximately the same numbers of cranes were observed by Tract C-a personnel, local ranchers, and Tract C-b personnel.

The aerial survey on October 22, 1975, was scheduled to coincide with the peak of migration (V. Salt, Bureau of Sport Fisheries and Wildlife, personal communication, 1975). Greater sandhill cranes were not observed during this survey. Solitary cranes, if present, were not detectable because turbulence and high velocity winds prohibited flying at a low altitude. On October 25, 1975, two flocks of greater sandhill cranes were observed on 84 Mesa by Dr. Alan Olson, the archaeological contractor for Rio Blanco Oil Shale Project. The flocks, consisting of five and six greater sandhill cranes, were observed approximately 1.61 km(1 mi) northwest of 84 Ranch. However, during the surveys conducted by Limnetics personnel on November 4-6, no sandhill cranes were observed.

D. Discussion

1. General Investigations - Habitats of rare plants are often geologically young or unstable: e.g., talus slopes, mountain tops, rock cliffs, or shale barrens (Smithsonian Institution, 1975). The endangered milkvetch, *Astragalus lutosus*, is known only to occur on dry calcareous shales at lower elevations in the drainages of the White River, Rio Blanco County, Colorado, and adjacent areas of Utah.

The Piceance Creek region, according to Barneby (cited in Munz, 1949), "is one of the two known locations of the very rare Astragalus lutosus . . . (The region is) part of the great Green River shale deposits, so rich in endemics to the west." Both specimens of the rare milkvetch were found growing on shale outcroppings.

There are three subspecies of the peregrine falcon in North America: Falco peregrinus anatum, Falco peregrinus tundrius, and Falco peregrinus paelei. Both Falco peregrinus anatum and Falco peregrinus tundrius are endangered. Breeding populations of the endangered Falco peregrinus anatum have declined in the Rocky Mountain region of their range during the last twenty years. During 1974, five Falco peregrinus anatum pairs in Colorado were successful in producing fledglings. Only three nesting pairs were successful in 1975 (G. Craig, Colorado Division of Wildlife, personal communication, 1975). Four peregrine falcons were observed on the study area during the reporting year of 1974-75; two of the four sightings were on Tract C-a. It is impossible to determine how many individuals (from one to four) the four sightings represent because of their high mobility. However, the sightings, in all probability, were the Falco peregrinus anatum subspecies since the observations occurred prior to the fall migration of the Falco peregrinus tundrius subspecies. The first migrating "tundra" falcons reach north-central United States in early September (Enderson, 1965). Peregrine falcon sightings on Tract C-a occurred during the spring and summer, 1975.

The status of the peregrine falcon(s) observed in the study area is unknown. The falcon(s) could have been either (a) solitary adult(s) hunting, (b) one of a pair nesting in the area, or (c) an immature. A basic component of the peregrine falcon's habitat is a cliff. Peregrine falcons are restrictive in the selection of their eyrie sites (Snow, 1972). Preferred cliffs are usually high, in close proximity to water, and favor a northeast directional orientation. The mean height of peregrine falcon nests in Utah was 54.3 m (178 ft) (Porter and White, 1973). In Colorado, all of the fifteen nests visited were on cliffs more than 70 m (210 ft) high (Enderson, 1965). Most peregrine falcon eyries in Utah were found on east and north

facing cliffs and were predominantly on open ledges under a cliff overhang (Porter and White, 1973).

Peregrine falcons often nest in the vicinity of rivers (Enderson, 1965). All of the 40 suspected eyries in Utah were in close proximity to water, i.e., rivers, marshes, lakes, and streams (Porter and White, 1973). Bend (1946, cited in Porter and White, 1973) reported that peregrine falcons in the western United States seldom nested more than 0.8 km (0.5 mi) from water in which to bathe. Furthermore, peregrine falcons are restrictive in their food habits; "water-type" birds are generally the preferred prey although the peregrine falcon does utilize other avian species for food. Of the available cliffs in the area, Cathedral Bluffs meets one nesting requirement, preferred directional facing of the cliff. However, an available source of water and food in close proximity to Cathedral Bluffs and cliff height appear to be limiting factors in the nesting potential of the area.

Gerald Craig of the Colorado Division of Wildlife supported the conclusion that the study area does not contain prime nesting habitat for the peregrine falcon. Thus, the peregrine falcon(s) observed were probably utilizing the study area and environs for hunting purposes only. A potential peregrine falcon eyrie exists approximately 32 km (20 mi) southeast of the study area and according to Mr. Craig, peregrine falcons could be hunting as far as 32 km (20 mi) away from the eyrie.

2. Greater Sandhill Crane Surveys

a. Spring Surveys - It is not known if the cranes observed staging on 84 Mesa during April, 1975, are Colorado nesters. The results of the spring aerial and ground reconnaissance combined with personal interview data provided no evidence that greater sandhill cranes nest in the areas in and around 84 Mesa. However, according to Blake (1974), when the young are a couple of days old, the adult birds lead them to higher ground or into the sagebrush to feed. Thus, the second portion of the ground survey may have occurred when adults had already led their young to feeding areas away from the water. Aerial and vehicle search for cranes may miss birds during the incubation period, due to the wariness of the birds and their ability to blend with the surrounding environment (W. Graul,

personal communication, 1975). Therefore, it is possible that the greater sandhill cranes observed staging in April, 1975 are Colorado nesters even though they were not detected during the study. They may be a local Rocky Mountain breeding flock that has gone unnoticed over the past years, or, because pioneering local birds seem to be moving into habitats which were historically occupied (Blake, 1974), a recent population may possibly have reinhabited the area. Reports from several residents on the White River and Piceance Creek concerning occasional sightings of cranes during past migration periods also suggest that the flock could have been a transient group foraging on 84 Mesa. It is undetermined if the observed greater sandhill cranes use these sites year after year or on an occasional basis.

b. Fall Surveys - The possible use of 84 Mesa as a fall staging area was investigated during September and October, 1975. Two flocks of greater sandhill cranes were observed on 84 Mesa on October 25, 1975.

Greater sandhill cranes usually remain for two to seven weeks at a fall staging area prior to their southward migration (Drewien and Bizeau, 1974). However, surveys of 84 Mesa that occurred on October 22 and November 4-6, 1975, during the peak of migration, did not reveal greater sandhill cranes. Thus, the two flocks observed probably utilized 84 Mesa as a temporary resting and foraging area during their southward migration.

The status of the flock observed October 8, 1975, near the confluence of Piceance Creek and Ryan Gulch is unknown. Some cranes migrating southward from northern staging areas will occasionally stop at staging areas farther south (Drewien and Bizeau, 1974). Greater sandhill cranes generally require available grain in proximity to an adequate water supply for their fall staging area (Drewien and Bizeau, 1974), but 84 Mesa does not seem to meet these criteria. In the fall, greater sandhill cranes generally move to the major staging area nearest their summer nesting site. Reports from several residents in the White River and Piceance Creek concerning occasional sightings of cranes during past migration periods suggest that portions of the Piceance Creek valley may serve as foraging sites for transient cranes. Thus, the flock observed on October 8, 1975, could have been either foraging and/or staging along Piceance Creek.

7.4 TERRESTRIAL INTERRELATIONSHIPS

A. Introduction - "Ecological interrelationships" is a phrase which encompasses all interactions among the multitude of organisms existing in the ecosystems under study and all interactions of those organisms with their abiotic environment. Although scientists profess an understanding for only a small proportion of the total of interactions, even those few are too numerous to be fully discussed in this report. Instead, the objectives of the following discussion will be (1) to outline some fundamental ecological concepts, and (2) to select examples of major ecosystem interactions specific to the Tract C-a vicinity, using them to develop the reader's intuitive grasp of the basic structure and functioning of ecosystems in the Tract C-a vicinity.

Most ecological interactions can be discussed within the framework of ecosystem food webs identifying the major pathways of energy and nutrient transfers. Organisms within food webs are commonly grouped into trophic (feeding) levels. The only significant source of energy in such a system is solar radiation absorbed by green plants and utilized in the conversion of carbon dioxide and water into energy-rich carbohydrates. For this conversion, the vegetation (referred to as the primary "producer" trophic level) is also dependent upon a suitable supply of nutrients from the soil. Thus, initially, the vegetation incorporates energy, water and nutrients from the soil. Energy-rich compounds produced in excess of the plants own requirements are stored in its tissues, ultimately providing the food base for the rest of the ecosystem.

Part of the vegetation is eventually harvested by "herbivores" (primary consumers) including certain insects, birds, and mammals while the remainder eventually pass to decomposition. Whereas the herbivores derive their nutrition directly from green plants (producers), carnivores (secondary or tertiary consumers) feed primarily upon the herbivores or upon other carnivores. A large portion of the biomass at each trophic level (producer-primary consumer, secondary and tertiary consumer) is not harvested by the next higher level (Boughey, 1968; Kormondy, 1969). For example, carnivores rarely consume entire prey populations.

There are several concepts fundamental to understanding the flow of energy and nutrients through trophic levels (producers to primary consumers to secondary consumers to decomposers, for example). First, the flow is directional. With respect to energy, it is noncyclic; with respect to nutrient flow, it is cyclic, with nutrients returned to the soil through the action of decomposers to again become available to producers. Secondly, because of incomplete harvesting and energy losses (e.g., to respiration, etc.) at each stage, there is a progressive decrease of energy (and usually biomass) at each successive trophic level). Thus, within a given category of organisms such as insects or birds, there would normally be more herbivores than carnivores. In fact, most ecosystems can support relatively few carnivores. Thirdly, the separation among trophic levels is based on ecological function. While the food habits of some species place them entirely within one trophic level, many animal species overlap trophic levels by consuming from more than one other category. For example, many organisms commonly consume both animals and vegetation and are called omnivores. Thus, although it is useful to illustrate broad ecological principles in terms of discrete trophic levels, such as primary producer herbivore, carnivore, omnivore, etc., complex food "webs" are more often encountered in the study of specific ecological systems.

In addition to the concepts of energy flow and nutrient cycling, another major concept involved in the following discussion of Tract C-a vicinity ecosystems involves the diversity of organisms, particularly within the lower trophic levels. This relates to the variety of cover and food sources available for partitioning among individual species at the higher trophic levels. It is easy to visualize that a carnivorous species dependent on a single prey population is also dependent on all those factors which affect the prey population. However, if the same carnivore has several optional food sources, it is to that extent less dependent on the factors which affect the population levels of a specific prey species. Conversely, small mammal or other prey species are less likely to achieve extremely high population levels (sometimes leading to destruction of their own habitat) if several predator species serve as controlling influences on their numbers. As a generality, those ecosystems with greater diversity in each trophic level (resulting in interactive food webs rather than linear food chains) are less likely to exhibit wide fluctuations

in component species and their population levels as a result of environmental stress (Wilson and Bossert, 1971). Fluctuations that do occur in such ecosystems are less apt to induce major oscillations in other components of the ecosystem.

To this point, only food-related interactions have been outlined. However, each animal species also has unique requirements for a place to live (habitat) including protection from its predators (cover), nesting or den sites, adequate living space and safety from other threatening factors such as climatic extremes. Plant species have comparable requirements for space, light, soil moisture and nutrients. Therefore, the discussion of the habitat requirements of important local species and their tolerance limits to disturbances from outside natural systems is important to local ecosystem descriptions.

The overall food web for terrestrial ecosystems in the vicinity of Tract C-a might be visualized in terms of a compartmental flow diagram (Figure 3-7-2). Although the diagram is a gross simplification of reality and is not intended to depict all possible interrelationships, it does identify some major expected pathways of energy and nutrient flow in Tract C-a ecosystems.

Producer organisms (vegetation) are supported by nutrients in the soil and respond to the various climatic factors (e.g., precipitation. temperature, humidity, etc.). All other organisms depicted on Figure 3-7-2 are directly or indirectly dependent upon the nutritional energy stored within the producer trophic level. The primary consumers which feed directly upon producers may be further subdivided according to their mode of feeding or the part of the plant which they utilize. Insects consume vegetation in substantial proportions and in various ways (e.g., as grazers, sap feeders, seed predators and pollen feeders). Small mammals, mule deer and herbivorous birds normally consume vegetation in lesser proportions.

Secondary groups are those animals which utilize primary consumers as a principal energy source, normally incorporating a small proportion of the energy available from the next lower level (MacArthur and Connell, 1966). Some insect groups (parasitic hymenopterans) and all spiders prey heavily upon

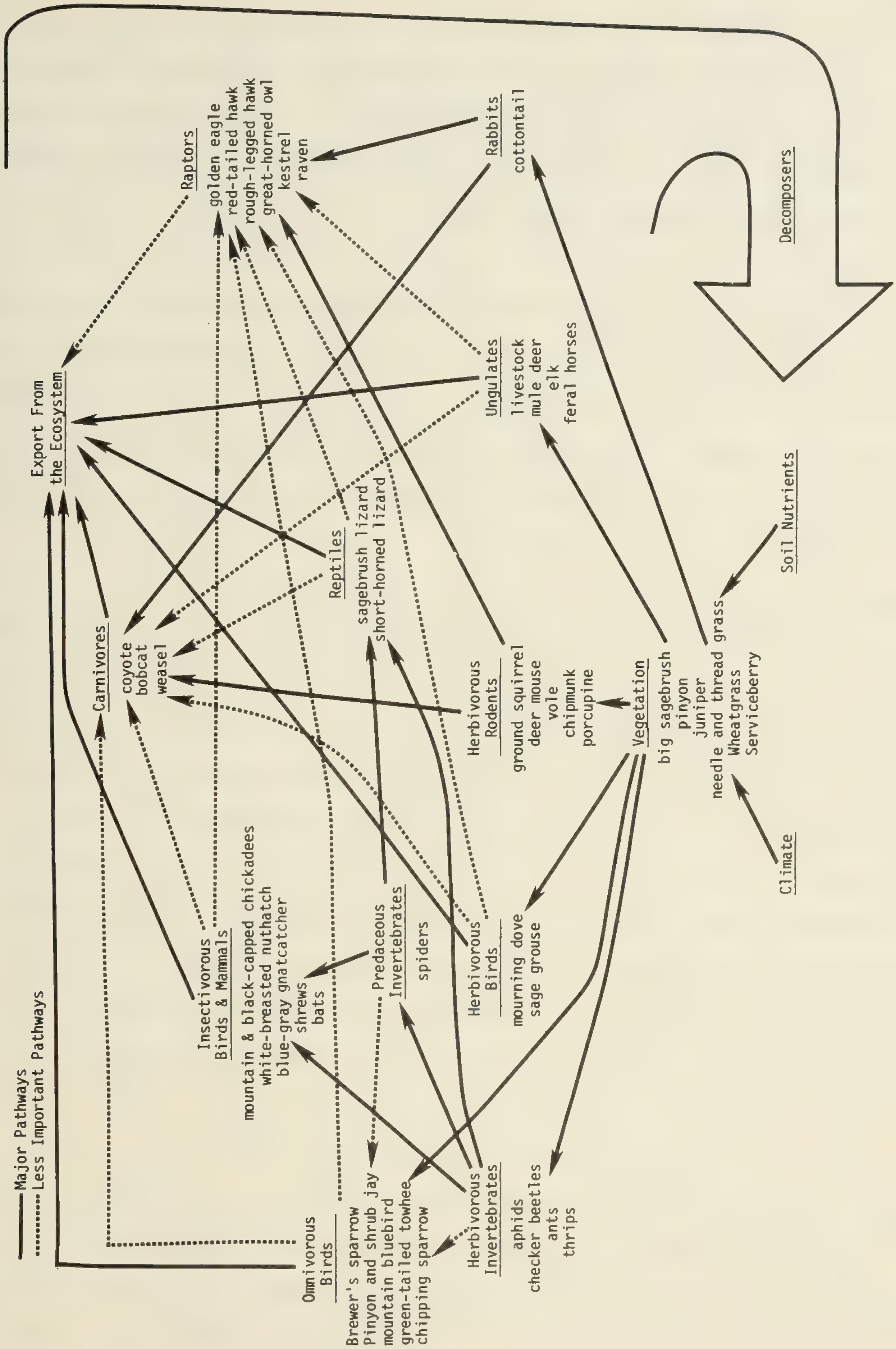

Figure 3-7-2

PATHWAYS OF ENERGY AND NUTRIENT FLOWS THROUGH TERRESTIRAL ECOSYSTEMS

herbivorous insects, for example. Raptorial birds, snakes, insectivorous birds and some mammals also derive nutrition from primary consumers. Considerable energy is lost in the transfer, hence, there are far fewer secondary consumers than primary consumers. Absence of these few top level consumers, however, could permit expansion in numbers of such groups as herbivorous insects, resulting in their overeating the producer organisms upon which they depend.

Using the above discussion of general ecological principles as a basis, the following discussion draws upon recent literature for the predominant vegetation types and upon study results from the Tract C-a vicinity to develop an understanding of major site-specific ecosystem interactions. In order to better focus on the most important interactions, the following treatment will deal principally with the pinyon-juniper and sagebrush vegetation types which cover 90% of the approximately 160 sq mi study area.

B. Abiotic-Producer Interactions - The necessary first step in understanding Tract C-a ecosystems is to understand how physical-environmental factors which prevail in the area may dictate the distribution and patterning of vegetation. Vegetation patterns, in turn, control major patterns in the distribution of animals. In the semi-arid, continental climate of the Piceance Basin the "controlling" environmental factors are relatively few and act in a more straight-forward manner than is common in more humid climates, creating a patchwork of distincly different vegetation types which are normally separated from each other by relatively distinct boundaries or zones of transition. The primary physical environmental factor which "controls" vegetation distribution in the Tract C-a vicnity is the availability of soil moisture in plant rooting zones. Availability of soil moisture is, itself, controlled by two interacting sets of influences.

The first is the physical-chemical nature of the soil. For example, coarse-textured soils effect rapid penetration of moisture to greater depths, with moisture frequently penetrating thin surface soils and extending into fractured bedrock. Here, especially where parent materials tend to be acidic, nutrient availability may be low. Such soils favor the growth of deep-rooted trees and

shrubs, particularly evergreens like pinyon or juniper which require a permanent supply of subsoil moisture but are adapted to low nutrient conditions. Most of the subsoil moisture is derived from winter snows. Summer rainfall is ineffective, lost by runoff or evaporation (Tueller, 1975). Fine-textured soils, on the other hand, tend to retain moisture in surface horizons and favor more shallow-rooted plants or shrubs, such as sagebrush, which are adapted to the higher nutrient availability typical of arid shrub-steppe soils. However, in arid regions like the Piceance Basin, surface soil horizons are frequently depleted of their moisture supply by late summer. Plants dependent upon surficial moisture must therefore be adapted to periodic drought, either by producing seed before the droughts (spring ephemerals) or by becoming dormant during the drought period (as in perennial grasses). This trend is most pronounced at the lower drier elevations of the Piceance Basin. For example, in the pinyon-juniper type on Tract C-a, the number of herbaceous species encountered was reduced from 39 species in July to 32 species in September. This differential was even more pronounced within the lower elevational range of the sagebrush type with a reduction from 60 herbaceous species in July to 30 species in September.

Soils tend to be geologically very young in the Piceance Basin and in some instances, plant distribution may be almost entirely dictated by the chemical nature of parent materials. For example, the desert-shrub (shadscale) vegetation type in the study area is almost entirely restricted to the light-colored geologic strata which frequently outcrop on south slopes. Chemical analyses to be performed on soil samples from these outcrops will likely reveal a definite saline-sodic chemical character imparted to the sedimentary parent materials by their environment of deposition. Thus, even if surface soils contain an appreciable amount of moisture, soil chemistry may make the water physiologically unavailable to all but those few species specifically adapted to such conditions.

In the pinyon-juniper vegetation type, which covers about 70% of the approximately 160 sq mi study area, differences in elevation and soil parent material effect considerable variation in species composition. The shallow, well-drained soils of the Rentsac Series are common to the pinyon-juniper woodland in the study area. These soils have been formed in residuum from sandstone and consist

of gravelly sandy loam which provides for rapid moisture infiltration. Pinyon-juniper woodland at lower elevations (below 2,100 m, 7,000 ft) is generally underlain by dry, poorly developed aridisols (Ward, Slauson, and Dix, 1974). At these lower elevations, where the parent material is composed largely of shales, Utah juniper may be the only tree present, and the scattered understory consists of stunted individuals of beardless wheatgrass, junegrass, needle-and-thread and Indian ricegrass (Ward, Slauson and Dix, 1974). Where sandstone composes the bulk of the parent material, Utah juniper may be joined by pinyon pine, but Utah juniper remains dominant. Big sagebrush, junegrass, western wheatgrass, needle-and-thread, and Indian ricegrass commonly comprise the understory at these sites. Soil profiles are better developed and plant productivity is usually higher here than on sites where shale forms the parent material (Ward, Slauson and Dix, 1974).

Pinyon pine becomes dominant within higher elevation pinyon-juniper woodlands (above 2,100 m, 7,000 ft) where the soils are usually well developed mollisols. The species composition and productivity of the understory is not so dependent on the soil parent materials at these higher elevation pinyon-juniper sites as is the case at lower elevations, possibly because of higher average annual precipitation at higher sites. Big sagebrush usually dominates the understory, but some serviceberry, chokecherry and mountain mahogany may also be present.

Much of the sagebrush vegetation type occupying bottomlands and valleys on and near Tract C-a is underlain by soils of the Glendive Series which are deep, well-drained and consist of fine sandy loam. Big sagebrush has a complex root system consisting of a long tap root with numerous lateral branches. This allows the plant to utilize moisture at a considerable depth as well as at the surface of the soil (Fautin, 1946). These plants attain their greatest size in bottomland areas in the vicinity of Tract C-a where sufficient soil moisture is available at a depth of 3-6 ft and where the salt content of the soil is very low.

Big sagebrush is sometimes found in association with greasewood in places where there is some salinity present in the subsoil (Ward, Slauson and Dix, 1974). But where big sagebrush does intergrade with greasewood in the vicinity of Tract C-a, it is normally found only along bottoms where the soil is deeper, more permeable and better drained than on adjacent slopes. Rabbitbrush commonly invades and dominates big sagebrush sites in the study area that have been disturbed by burning or cultivation. Several wheatgrass species in addition to Indian ricegrass are common understory species in the bottomland sagebrush vegetation type.

Tne sagebrush vegetation type occupying upland sites, (slopes and ridgetops) is underlain by soils of the Rentsac-Piceance Series. These soils are moderately deep, well drained and are composed of sandy loam to gravelly, sandy loam. Big sagebrush at these sites is much smaller in size than at bottomland sites probably because bottomland sites receive direct precipitation and runoff from adjacent slopes, as well as winter accumulations of drifted snow. Windswept ridgetops and mesas receive the least moisture, particularly at lower elevations such as 84 Mesa where a low-growing, stunted sagebrush community exists. Typical understory species at upland big sagebrush sites include junegrass, wheatgrass, and needle-and-thread.

In summary, within the overlapping elevational ranges of pinyon-juniper and sagebrush vegetation types of the study area, the two types are segregated by the differing abilities of dominant species to compete with each other under differing physical-chemical soil conditions. Within the elevational range of the two types there is a tendancy for big sagebrush to occupy the valleys, mesas, or gentle slopes where fine-textured soils are prevalent. The pinyon-juniper type occupies the ridges, canyons, or steep slopes where coarse, rocky soils predominate. On soils intermediate in texture and depth there is a great deal of competition between big sagebrush, pinyon pine and Utah juniper.

The second set of influences affecting soil moisture availability is that of macro-and microclimate. Microclimatic conditions, as they affect soil moisture, are largely controlled by elevation, the direction of slope relative to the location of the sun (aspect), slope steepness and prevailing winds. Briefly, increases in elevation correlate with increases in precipitation and lower evaporation rates (due to cooler temperatures). In these northern latitudes the sun is always to the south. Therefore, south slopes receive the greatest amount of insolation, creating the most rapid rates of evaporation, particularly in the hot afternoon (southwest slopes) and on steeper slopes. This relationship is even more pronounced in the Tract C-a vicinity because prevailing winds during the growing season are also from the southwest (Chapter 6). Thus, soil moisture depletion by evaporation and by transpiration from plants is much greater on southwest than on northeast slopes, and this is a predominant influence upon vegetation distribution in the area. Precipiation variability, as well as quantity and seasonal distribution, exert an important influence on vegetation of the Tract C-a area. The drier years effectively determine the dominant perennial vegetation which must be capable of surviving the variations of climate. During periods of above average precipitation, several minor species may become very abundant (especially annuals since they have a short life cycle and high seed production), and overall vegetation cover may increase substantially. In fact, seeds of many species in semi-arid regions will not germinate except in years that are wetter than normal. Populations of such species, however, are rapidly reduced by one or two drought years.

Of course, not quite all abiotic factors influencing the distribution of vegetation in the Tract C-a area can be discussed as controlling factors operating through their effect upon soil moisture availability. For example, fire may radically alter plant distribution patterns. Fires in the pinyon-juniper type may destroy the trees and encourage a dramatic increase in cover by sagebrush and perennial grasses. About 45 years following a fire the trees gradually take over from sagebrush and perennial grasses (Frischknecht, 1975). Fire and mechanical removal of sagebrush at a number of locations on

and near Tract C-a, have obviously allowed rabbitbrush communities to take over in areas previously occupied by big sagebrush. Big sagebrush does not sprout when stands are destroyed in wildfire. However, rabbitbrush, which is a seral dominant in many big sagebrush communities, sprouts profusely after the fires destroy aerial portions of the sagebrush plants (Young and Evans, 1974).

In the final analysis, although factors controlling the distribution of vegetation in arid regions are more readily evaluated than those in more humid areas, local plant communities and ecosystems are still highly variable. "Early attempts to explain distribution, composition, successional changes and management responses in terms of single factors were overly simplistic. These variations can be better explained in terms of a complex of environmental patterns, historical events, and successional mechanisms" (West, et al., 1975). On Tract C-a the ordination of vegetation with elevation, slope and aspect in the pinyon-juniper type was similar to that found by West, et al. 1975, (see Section 7.1-A, Second Annual Report, RBOSP, 1976). Also in the mixed brush type at Tract C-a there was an increase in cover with increasing elevation and a response to differences in slope and aspect. However, the serviceberry-snowberry association of the mixed brush type showed much more variability in cover than did the serviceberry-Gambel oak association. This illustrates that although much of the patterning of vegetation at Tract C-a is attributable to variations in soil moisture (as affected by elevation, slope and aspect) the biotic and physical environmental factors are importantly affecting vegetation distribution on a micro-scale.

C. Producer -- Primary Consumer Interactions - Given the above outline of how physical/environmental factors may influence vegetation distribution in the Tract C-a area, we may turn attention to how vegetation distribution, in turn, influences the animals (primary consumers) which depend upon the vegetation as a primary source of food and shelter. Conversely, if animal numbers become large they may influence the distribution and vigor of the plants upon which they depend. Although the relative impact of different

consumer groups upon vegetation may vary with time and from one locality to another, there is a general pattern which may be applied. The following discussion treats the primary consumers of Tract C-a in the order of their potential (from highest to lowest) for affecting the plants (producers) upon which they depend.

In general, herbivorous insects have the greatest potential for consuming their plant hosts to a degree which could affect plant vigor and distribution.

Aphids, thrips, checker beetles and ants are the most important herbivorous insects found within the pinyon-juniper and sagebrush vegetation types on the study area. These insect groups are either plant tissue or plant sap feeders (aphids and ants), flower feeders (thrips and checker beetles) or seed feeders (ants) and in their feeding habits can often cause moderate to severe damage to their food species.

Ants are probably the most numerous insect group encountered in both the sagebrush and pinyon-juniper vegetation types. They are primarily seed eaters and where their numbers are large they gather and consume vast quantitites of seeds. Ants have been frequently observed accompanying and attending aphids in both sagebrush and pinyon-juniper vegetation types. The aphids feed on plant sap (sagebrush, rabbitbrush and others) and the ants are instrumental in moving the aphids to unconsumed portions of the food plant and in protecting them from predators. The ants in return feed on the waste products of the aphids. Ants, through their burrowing activities, often play an important role in the aeration and loosening of these arid soils. They also perform other important arid soil formation activities that are similar to those credited to the earthworm in more moist areas (Fautin, 1946).

Pinyon and juniper in the study area both support heavy populations of Miridae (leaf feeding insects). In addition, several species of wood-boring beetles have been identified on pinyon pine. Frischknecht (1975) reported that grasshoppers (also common in the study area) feed on the surface of juniper berries causing them to wither, crack open and fall to the ground. Keen (1973)

local ranchers identified range conditions as being better in the 1975 season than at any time in recent years. A breakdown of the range analyses into contributing components (such as soil condition, plant vigor, and browse condition) reveals that most components were low or in a downward trend but were overbalanced by unexpectedly high numbers of desirable forage species (Section 7.1.C, Range Analysis). A widespread downward trend for surface soil conditions and a rate of forage production are other indicators, both of which suggests a long-term decline in the capacity of Tract C-a rangeland to support current levels of ungulates.

The general observation of younger juniper trees at the forest edge and juniper saplings and seedlings extending well out into adjacent vegetation types lend credence to the view that here, as elsewhere throughout the Great Basin province, the pinyon-juniper type is extending its range at the expense of adjacent vegetation types which are potentially more productive.

Mule deer show seasonal preferences with regard to forage utilization. They consume primarily browse but also utilize grasses in spring and forbs in summer and fall. Mule deer depend almost exclusively on browse during the winter months. Since mule deer are primarily browsers, they seldom do serious damage to the vegetation. In fact, to a certain degree, their browsing can stimulate some shrub species (e.g., serviceberry, Gambel oak) to increase production of twigs (Shepherd, 1971; Hill, 1956). However, excessive browsing which often results from overcrowding of mule deer can kill or reduce the browse species.

Browse conditions in the Tract C-a study area were overwhelmingly in the "good" condition class. The largest portion, however, was seen to exhibit downward trend or a deterioration in condition (Section 7.1.C, Range Analysis). Mule deer use the study area primarily during the transitions between winter and summer range, except in mild winters (Section 7.2.B, Large Mammals). This, and the fact that mule deer which utilize the area for winter and transitional ranges have decreased drastically in numbers since the 1950's, may account for the favorable condition of browse which prevails the evidence that this favorable condition is deteriorating may correspond with increasing numbers of wild horses which may utilize browse species heavily when snow depths prevent access to preferred herbaceous species.

reported that insects can destroy as much as 90% of the pinyon pine cone crop when infestations are heavy. Although many herbivorous insects are often regarded as pests they do play a vital role in the food web of local pinyon-juniper and sagebrush ecosystems by providing an important food source for lizards, birds and insectivorous mammals such as shrews and bats.

The second consumer group, in order of potential for utilizing its plant resources, is that of the ungulate large mammals. This group includes domestic livestock, wild horses, elk and mule deer. Presently, the most significant producer-ungulate consumer interaction is that between pinyon-juniper/sagebrush vegetation types and domestic livestock. Man's introduction of unrestricted grazing by domestic livestock a little more than a century ago filled a large herbivore ecological niche that had been relatively unexploited since the close of the Pleistocene. This greatly altered plant succession in the Great Basin (Young and Evans, 1974) and led to reduced herbaceous competition and increased dispersion of seeds in animal feces. Primarily for this reason the pinyon-juniper type has so extended its range that much of the present pinyon-juniper is a recent phenomenon. "The trees have invaded what was formerly savannah, grassland or shrub steppes; both upslope and down... Simultaneous with the invasion of new areas was the substantial increase in tree density within stands in existence over 100 years ago. The trees have replaced formerly more abundant shrub and herbaceous understory" (West, et al., 1975). Even with the encroachment of pinyon-juniper onto adjacent rangelands and the reduction in herbaceous understory, range managers commonly regard pinyon-juniper as the most valuable vegetation type for livestock production west of the 100th meridian (Dwyer, 1975). This vegetation type is often chained to remove the overstory thereby increasing production of forage species and increase its value as cattle range.

Most cattle in the vicinity of Tract C-a are herded into higher elevations through the warm months but then are concentrated in lower elevation meadows where they are fed hay throughout the winter. Range analysis performed over three Bureau of Land Management grazing allotments in the Tract C-a area revealed local ranges to be in a generally moderate condition even though

Mule deer may play an important role in the structure of pinyon-juniper stands east of Tract C-a. Hansen and Dearden (1975) pointed out that during severe winters a large percentage of the mule deer's diet consists of pinyon pine and that juniper is also an important dietary item for this species. In dense pinyon-juniper stands, the cropping back of the saplings and seedlings of these two tree species at the forest's edge by mule deer when other, more preferred, browse species are not available can retard the spread of the forest. As the older trees die out there are no younger trees to take their place. When a dense forest is thinned, a greater amount of solar energy is allowed to reach the forest floor resulting in a proliferation of the herbaceous and shrub strata.

Where chaining or burning has been used to remove pinyon and juniper trees in favor of preferred forage and browse species, browsing pressure may help to prevent the trees from regaining dominance (Stephens, et al., 1975).

Although pinyon and juniper are advancing throughout the Tract C-a area, the high-lined trees and stunted (frequently killed) saplings and seedlings at the forest border are ample evidence that this advancement is being retarded by browsing. East of Tract C-a, at the edge of the winter range for a portion of the Piceance Basin mule deer herd, large numbers of mule deer may concentrate on stands of pinyon-juniper and sagebrush vegetation. For example, observations last winter on lower elevational zones east of Tract C-a indicated heavy mule deer utilization of serviceberry, where pinyon-juniper and sagebrush types intergrade. In each area, the deer can find both the greatest variety of browse species (pinyon-juniper, sagebrush, serviceberry, bitterbrush, and mountain mahogany) and at the same time take advantage of the cover and protection from cold and wind afforded by pinyon and juniper trees. Aerial census results indicate that deer avoid large, open areas of sagebrush during the cold months even though these areas would provide considerable browse.

Wild horses are numerous(herds up to 30 individuals have been observed) west and southwest of Tract C-a and on 84 Mesa throughout the year. In these areas the wild horses consume considerable amounts of herbaceous vegetation during the summer months and browse and herbaceous vegetation during the winter. Wild

horses are observed on windblown ridges where they forage uncovered grasses during winter but they also frequent the pinyon-juniper forests. It is assumed that even though these forests probably do not provide all of the preferred dietary items for wild horses, they are used extensively for cover and as warm places out of the wind to bed down. Wild horses are much more mobile (because of their large size) in deep snow than are mule deer and are therefore able to travel greater distances from a bedding area in a pinyon-juniper stand to open areas which provide suitable forage. In areas where mule deer and horses occur together in the Tract C-a vicinity, the wild horses will often clear paths through the snow which are used by the mule deer in their search for palatable forage.

Elk have been infrequently observed in the area of Tract C-a and probably only occur there in very small numbers, exerting very little influence on the native vegetation.

No ungulate species (elk, mule deer, wild horses or domestic livestock) can be considered an obligate browser or grazer. Rather, each tends to be opportunistic, relying on the most palatable or nutritious forage available at a given time of the year. Mule deer which have been described primarily as browsers, for example, rely heavily on browse during colder months when grasses lose much of their nutritive value and become buried under the snow. However, when fresh herbaceous vegetation becomes available in the spring and early summer, the mule deer will feed heavily on it. Wild horses, which are categorized primarily as grazers, will utilize herbaceous material and have been observed both pawing the snow to uncover palatable grasses and foraging on windblown ridgetops where the snow cover is gone and where utilizable herbaceous material is available. Wild horses do, however, become increasingly dependent on woody vegetation during the colder months when less herbaceous vegetation is available for consumption.

Small and medium-sized herbivorous mammals and birds may be combined in a common category representing the third and least likely consumer group to

affect the vigor and distribution of vegetation upon which they feed. Nonetheless, herbivorous small mammals and birds, as primary consumers, often play a vital role in the distribution of certain plant species that they feed upon. Frischknecht (1975) stated that seed dispersal by birds and mammals is perhaps the most important mutualistic effect of pinyon-juniper faunal/vegetation relationships. This is probably also true for the sagebrush ecosystem. Both juniper and pinyon seeds, for example, can be carried long distances from their source both in the cheek pouches of small mammals such as chipmunks or in the feces of animals such as cottontail rabbits or pinyon jays and others. It has been speculated that some seeds passed by animals germinate more readily than others and also that some seeds remain viable for longer periods of time after passing through the digestive systems of certain animals (Johnson, 1962). Parker (1945) attributed invasion of certain grassland areas by juniper to distribution of seeds by animals.

Several herbivorous small mammal (e.g., piñon mouse, Colorado chipmunk, bushy-tailed woodrat) and bird (e.g., pinyon jay) species are found almost exclusively within the pinyon-juniper vegetation type in the study area. All species appear to be associated with the pinyon-juniper vegetation type in the study area by their food and nesting requirements. Piñon mice, pinyon jays and Colorado chipmunks depend directly on pinyon and juniper for both food (they feed on pinyon nuts and juniper berries) and nesting material. Woodrats nest in juniper stumps and in the many rock outcroppings prevalent in this vegetation type throughout the study area. They also depend heavily on pinyon nuts and juniper berries as a food source.

Data collected during live-trapping operations from over 2,700 individuals, comprising 13 small mammal species, have permitted the formulation of several generalizations concerning the distribution and abundance of small mammal populations among major habitats within the area of investigation at Tract C-a and during the October, 1974 to October, 1975 sampling period (Section 7.2.A, Small Mammals). Within habitats sampled below 8,000 ft elevation, the amount of shrub cover appears to be the most important factor regulating the abundance of small mammals. The largest number of small mammals captured per unit trapping effort (i.e., individuals/100 traps) occurred on grid 3 (rabbitbrush), followed in order by grid A (greasewood-sagebrush) and grid 5 (mixed brush).

Vegetation data collected from permanent phytosociological transects on or near small mammal grids showed that these grids also exhibited the highest shrub cover of all grids below 8,000 ft (Table 3-7-1). Accordingly, the grid with the fewest captures below 8,000 ft, grid 1 (bottomland meadow), also exhibited the lowest shrub cover.

Although the same trend holds true for grids above 8,000 ft, i.e., more small mammals are encountered in habitats with a higher shrub cover, total small mammal abundance is lower for these grids than for those a lower elevations. This is likely due to the harsher conditions and shorter growing season at the higher elevation.

Species diversity, as indicated by the Shannon-Weiner index which accounts for both number of species and number of individuals of each species, seems to be tied closely to the presence or absence of trees (i.e., pinyon-juniper) in habitats below 8,000 ft. Pinyon and juniper trees provide food for many small mammal species that eat the highly nutritious pinyon nuts and juniper berries. The latter are more consistently available than pinyon nuts as they remain on trees a large part of the year and are not so completely destroyed by insects as pinyon nuts (Frischknecht, 1975). The cambium of pinyon may also be eaten by certain species such as porcupines and the shreddy bark of juniper is often used in nest building (Frischknecht, 1975).

The value of pinyon and juniper trees as a source of food and potential nesting sites is further emphasized when it is noted that eight of the thirteen species encountered during all live-trapping operations inhabited pinyon-juniper woodlands. In fact, three of the species, piñon mouse, Colorado chipmunk, and the bushy-tailed woodrat were generally limited to this vegetation type.

At elevations above 8,000 ft the harshness of the environment and not the presence or absence of trees is probably a more important determining factor in the distribution of small mammals. Of the 13 species encountered, only 5 were captured in grids established at the higher elevations. Furthermore, only one trappable small mammal species, the red-backed vole, is specifically adapted to the environmental extremes of the higher altitudes (Lechleitner, 1969).

The two most abundant small mammal species within the vicinity of Tract C-a are the least chipmunk and the deer mouse. Both were represented in samples from every grid and together accounted for 82.4% of the total small mammal abundance. The habitat affinities of the least chipmunk and the deer mouse were almost identical with both species being caught more frequently in habitat types with high shrub cover.

Of the three most common species collected by removal trapping for analysis of stomach contents, two, the least chipmunk and the deer mouse, indicated preferences for seeds. However, both utilized succulent materials more frequently in the spring when new seeds were not yet abundant. The deer mouse was slightly more omnivorous in its food habits as invertebrates and vertebrate materials were occasionally observed in stomach contents. Long-tailed voles, collected within the aspen vegetation type, utilized primarily succulent materials. However, it too was opportunistic when its favored food was not available as a high percentage of seeds were found in stomachs of specimens collected in early spring.

Porcupines may have a special and severe effect upon pinyon pine distribution, particularly in restricted areas used as "yards" in winter. Much porcupine damage to pinyon pine has been observed in the area of Tract C-a. Porcupines show a preference for the bark and cambium layers of pinyon pine trees and in their feeding, often girdle (remove all bark and cambium in a 360^{o} circle around the tree) the tree and in so doing, cause it to die.

Bird species which are predominantly herbivorous and characteristic of the study area include the sage grouse and pinyon jay. Sage grouse are an important inhabitant of the sagebrush and mixed brush vegetation types in the study area. They depend heavily on big sagebrush for food and nesting sites. Large open areas prevalent within many sagebrush sites, serve as displaying ground (leks) during the breeding season. Sage grouse frequently retreat to the denser stands of sagebrush on the study area where they roost, feed and seek shelter. The pinyon jay is an extremely gregarious bird. Individual flocks may commonly return to a traditional breeding ground year after year to nest and rear their young (Frischknecht, 1975). Then in late summer, they

may congregate again in the same area to gather and cache pinyon nuts, indicating a strong reliance upon pinyon nuts for reproduction in the following spring (Balda and Bateman, 1971).

D. Primary Consumer-Secondary and Higher Order Consumer Interactions - The most diverse and populous group of these higher order consumers is the invertebrate group, including insects, spiders and centipedes. Several species of insects are carnivorous in larval stages and herbivorous as adults.

Mammalian predators include the shrews and bats, which feed primarily on insects, and the coyotes, bobcats, weasels and badgers which mainly eat birds, mice, rabbits and ground squirrels. Coyotes and weasels (longtail weasel and ermine) appear to be the most common mammalian predators in the vicinity of Tract C-a (Section 7.2.C, Mammalian Predators). Both species range throughout the pinyon-juniper and sagebrush vegetation types where they feed on small mammals, birds, birds' eggs and carrion. Coyote food habit studies cited by Fautin (1946) indicate that this species feeds upon all types of rodents, birds, reptiles, insects and even some vegetable matter. Sperry (1941) reported that rabbits occurred in 43% of the 8,339 coyote stomachs he examined. Seasonal rodent abundance probably plays an important part in coyote dietary habits in the study area. Lagomorph studies indicate that rabbits are not presently abundant and therefore probably do not play an important role in the coyotes' diet at this time. Although dietary information for the coyote has not been gathered in the study area, it can be assumed that when rodents, such as ground squirrels and chipmunks, become abundant during the warm months, they are probably fed upon extensively by the coyotes. During the winter period, however, when these rodents are inactive, the coyote probably resorts to feeding heavily on carrion provided in abundance during some winters by natural mule deer mortality in the study area. Rasmussen (1941) examined coyote scat collected during mid-winter from a pinyon-juniper ecosystem in northern Arizona. He found the scat to consist mainly of deer hair and bones, some rabbit fur and the remains of deer mice. He found both mule deer carrion that had been fed upon by coyotes and fresh mule deer that had been killed and eaten by coyotes. Coyote scat that was collected during summer from the same area by Rasmussen (1941) consisted primarily of juniper berries, serviceberries, prickly pears, grass and rodent remains. Signs of bobcat

and badger have also been recorded in the study area but these species do not appear to be common and therefore probably exert little influence on local prey populations.

Insectivorous mammals such as shrews and bats have not been recorded in large numbers in Tract C-a vicinity pinyon-juniper and sagebrush ecosystems.

Bats have been captured in mist nets near the few isolated pockets of open water in the study area where they regularly feed on airborne insects at dusk during the summer months. Bats probably roost by day in the rock outcroppings and rock crevices prevalent throughout the pinyon-juniper vegetation type in the study area. Bats have been known to consume large quantities of insects in certain areas where their populations are large and in certain parts of the country, they have been credited with controlling the numbers of potential pest insects. Shrews also feed voraciously on insects but this order of small mammals has not been recorded regularly for Tract C-a sagebrush and pinyon-juniper ecosystems. Shrews by nature are elusive and very difficult to capture by conventional live-trapping techniques. Since so few have been captured in the study area to date, it is difficult to speculate on their importance in local ecosystems.

Avian predators like the common flicker, the white-breasted nuthatch and the blue-gray gnatcatcher (primarily insectivores) consume large quantitites of insects. The predatory hawks, owls, falcons and eagles prey on small mammals and birds and help to limit the populations of these animals. The ravens are generally scavengers but have been known to take live prey, particularly small mammals and birds.

Golden eagles, great horned owls, kestrels and ravens are the most important year-round avian predators in the study area (Section 7.2.D, Avifauna). Red-tailed hawks are common during the warm months in the study area, but their numbers dwindle with the onset of winter. Rough-legged hawks are common on the study area only during winter.

Golden eagles range throughout the entire study area during all seasons. They are opportunistic in their feeding habits and their diet in the region

of the Piceance Basin ranges from mule deer carrion in the winter to rodents such as ground squirrels during summer. In other areas, golden eagles have been known to feed heavily on rabbits when this group is abundant.

Great horned owls are found throughout the pinyon-juniper and sagebrush vegetation types on the study area during all seasons of the year. They seem to prefer nesting along rock cliffs and outcroppings prevalent along washes and gulches throughout the pinyon-juniper ecosystem. Owl pellet studies conducted south of Tract C-a indicate that the great horned owl in this area of the Piceance Basin feeds almost exclusively on microtine rodents (voles) throughout the year.

Kestrels are common throughout the pinyon-juniper and sagebrush ecosystems year-around, although their numbers in the study area dwindle during winter. Kestrels feed more heavily on insects during the warm months, except during the period when they rear young. At that time, kestrels feed more heavily on small mammals as a food source probably because of the greater energy demands placed upon them by their young. During fall, kestrels have been observed consuming large quantities of grasshoppers in the study area.

Ravens are common scavengers found throughout the study area all year. They have been observed feeding on both dead cattle and mule deer during winter. Pellet studies indicated that ravens in this region of the Piceance Basin also feed on small mammals and birds. Both red-tailed and rough-legged hawks range throughout the region where they feed upon a wide variety of rodents, including deer mice, voles, ground squirrels and chipmunks.

Sagebrush and short-horned lizards are the most common predaceous reptiles in the study area. They have been recorded in abundance in pinyon-juniper stands where deadfall and rock outcroppings provide adequate cover. Both reptile species are insectivorous and are only active during the warm months. Marcellini and Mackey (1970) demonstrated quantitatively that the sagebrush lizard is primarily a ground dweller in the western part of its range. Turner (1974) in a study in western Colorado, observed the sagebrush lizard on the ground 57% of the time. Turner (1974) also found that ants (Formicidae)

accounted for 59% of the lizard diet while beetles (Coleoptera), caterpillars (Lepidoptera), bugs (Hemiptera) and larvae were also important food items.

E. General Discussion of Terrestrial Interactions - It should be emphasized as was pointed out at the begining of this discussion, that terrestrial ecological interactions are far more varied and complicated than is implied in the simplified treatment above. Many species commonly associated with given trophic levels are more properly classified as omnivores. This group includes the shrews, coyotes, mice, ravens, mountain bluebirds and green-tailed towhees. A good example of omnivory is exhibited in the food habits of coyotes. As previously stated, they consume vegetable matter as well as insects, mice, eggs, young birds and carrion. A diversified diet allows an animal to be opportunistic in its forays for food and relatively independent of the availability of single food items.

Other kinds of interactions could be discussed in addition to those above. One could discuss producer-producer interactions. The proliferation and expansion of the pinyon-juniper tree stratum, (which can result when increasing livestock grazing pressure or fire reduces the competition for water and minerals normally exerted by the herbaceous and shrub strata) can also have profound effects on the composition and density of the herbaceous and shrub strata. As the tree canopy becomes more closed, it not only reduces the amount of solar energy reaching the forest floor, but it also produces greater accumulations of litter. This has been the prevailing, recent pattern in pinyon-juniper forests (West, et al., 1975). Jameson (1970) has indicated that toxic substances (phenolic compounds) in the scales of juniper can have an inhibitory effect on grass growth. These same phenolic compounds exuded by juniper scales may also inhibit the natural processes of decomposition (by their effects on the bacteria) essential for nutrient cycling (Jameson, 1970).

There are also important interactions involving the direct influence of physical environmental factors upon primary consumers. Invertebrate groups having the greatest potential for negatively influencing their plant hosts seldom do so except under infrequent climatic regimes which favor maximum population growth.

Results of 1975 big game studies around Tract C-a indicated maximum deer concentrations in the lower shrub and pinyon-juniper communities on north slopes. However, in severe winters (those most critical to big game population density) deep snows on north slopes force the deer to utilize the less favorable southwest slopes which are cleared sooner by more direct sunlight and prevailing winds. Thus, the most critical factor limiting the growth of big game herds is apt to be the extent and quality of winter range on southwestern slopes. Finally, many animal species depend to some degree on the availability of drinking water.

Physical environmental factors may directly affect secondary consumers as well. For example, eagles may be highly opportunistic in the taking of prey and carrion. However, their requirements for suitable nest sites are highly specific. Thus, eagle populations may depend more upon the availability of suitable, remote cliff sites than upon food supplies.

Although decomposer groups have not been included in current studies because of the inadequacy of available field techniques, their activity is of primary importance to overall ecosystem functioning. By far, the greatest proportion of the annual production of non-crop vegetation in the study area falls to the ground as leaf or grass litter. Much of this is broken down by decomposers such as fungi, bacteria and soil arthropods. Insect groups such as Collembola, Diplura, Psocoptera, Acari and Thysanura, which are found in abundance at many pinyon-juniper and sagebrush sites in the study area, are all soil-litter inhabiting scavengers, and therefore play a vital role in breaking down detritus (non-living plant and animal matter). Any interference with these groups, and therefore with the recycling of nutrients back into terrestrial ecosystems, will have repercussions throughout local food webs.

A habitat type of special importance because of its limited distribution in the Tract C-a area is riparian habitat. Locally rare species, including amphibians such as the chorus frog and tiger salamander, use the water among other things for protection against mammalian and avian predators. Great blue herons feed on aquatic vertebrates and many ducks feed on aquatic plant and animal life.

Tree, cliff and violet-green swallows feed heavily on the many insects that swarm over the few water impoundments in the study area. Killdeer, yellow-legs and sandpipers, observed at study area impoundments, feed on submerged aquatic invertebrates as well as some aquatic vegetation.

Finally, the influence of man on all trophic levels cannot be underestimated as an important factor affecting local ecosystems. He exports a large amount of the local green biomass production through livestock grazing, thus removing both energy and nutrients from local food webs and nutrient cycles. As a predator, man takes commercially important game species (such as rabbits, mule deer, sage grouse and waterfowl). Control of "pest" species, such as the coyote can have drastic effects upon local ecosystems. Attempts to remove a major element of local ecosystems, particularly a top level carnivore, are certain to change nearly all relationships among the remaining elements in ways that cannot presently be predicted. Man's influence cannot be extracted from consideration of local ecosystem interactions because man is a predominant herbivore and carnivore controlling much of the area's production, and at the same time introducing totally new influences into local environments. The accuracy with which we predict the effects of influences such as oil shale development is dependent, in a major way, upon how well we understand the critical elements of structure and function and man's potential for influencing those elements in existing local ecosystems.

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CHAPTER 8

AQUATIC ECOLOGY

SECTION 3

BASELINE CONDITIONS

CHAPTER 8

AQUATIC ECOLOGY

The Rio Blanco Oil Shale Project (RBOSP) Aquatic Baseline Studies are intended to perform those environmental studies described in the Federal Register, Volume 39, Number 230, Part 3, Oil Shale Lease Environmental Stipulations; and in the Tract C-a Exploratory Plan of May 1974 as approved in the "Conditions of Approval" agreed to by letter in August 1974. Specific lease requirements addressed were "The Lessee shall make studies of the flora and fauna. . .and also of the aquatic habitat as far downstream as the Mining Supervisor shall require."

A limited variety of aquatic habitats occur on or near Tract C-a. These habitats include small springs and seepage areas, small marshy ponds, and small spring-brooks. Several miles north of the tract is the large, turbulent White River, the only true river habitat in the Piceance Creek Basin. Until the present baseline studies, no detailed studies of the aquatic ecosystems on or near Tract C-a had previously been undertaken.

The overall objectives of the RBOSP Aquatic Baseline Studies are to characterize the existing aquatic communities on and in the vicinity of Tract C-a and to inventory aquatic habitats which may be affected by oil shale development.

In order to fulfill the program objectives, a total of 35 sampling sites were selected to represent the aquatic habitats present. Emphasis in this aquatic program has been given the two permanent streams, Yellow Creek and the White River, where 18 stations have been located. The locations of aquatic sampling stations are shown in Figure 3-8-1 and described in Table 3-8-1. In this report, the stations are

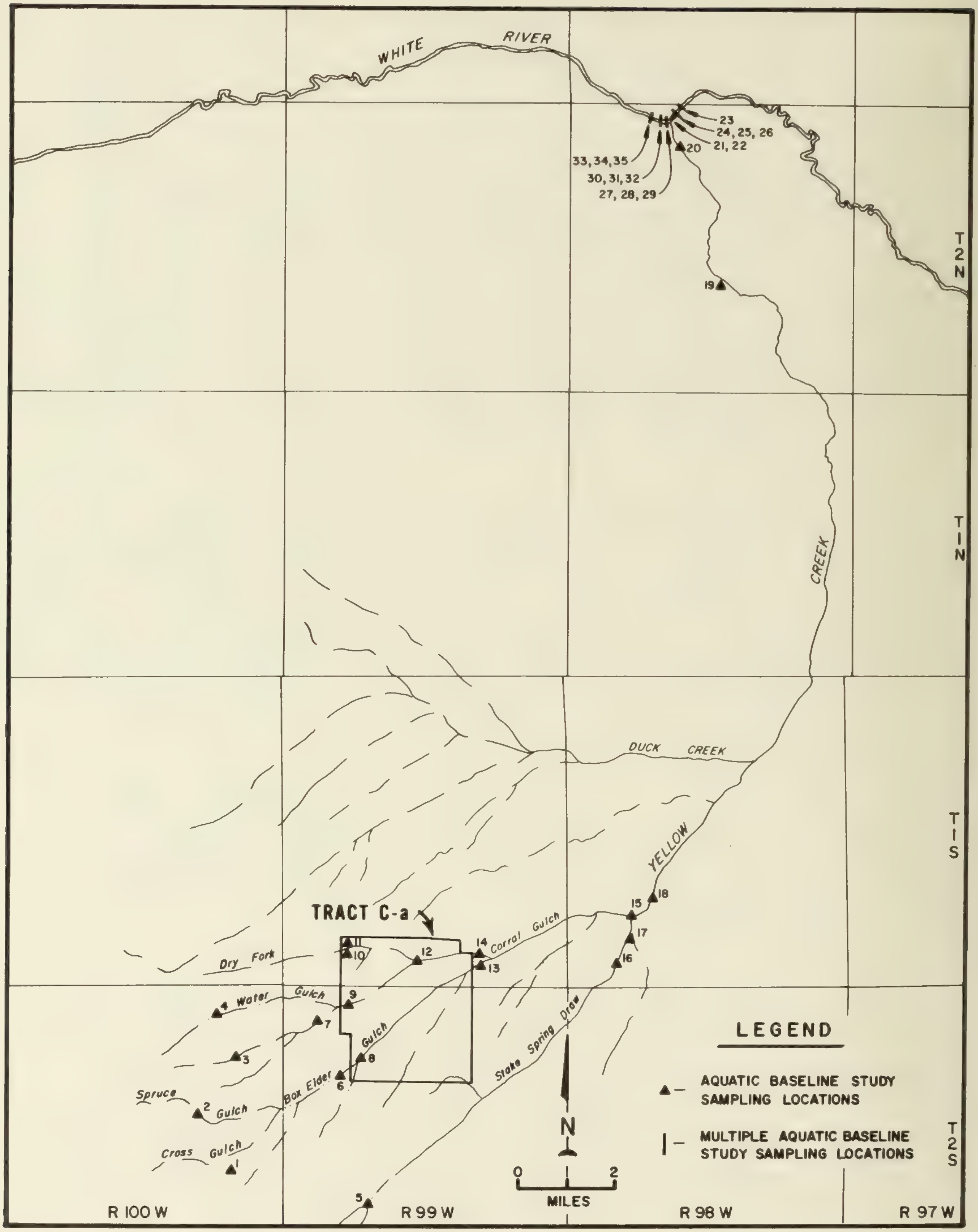

Figure 3-8-1. RBOSP Aquatic Sampling Locations

Table 3-8-1. Location of Sampling Stations

Station	Location
1	Cross Gulch Headwaters approximately 3,200 meters (2 miles) above the confluence with Spruce Gulch. This is the lowest of the three springs in the area. This station is located at the highest elevation of all the stations. All of the seepages in the vicinity of this station have been tapped for use in livestock watering. Nearby aspen trees appear to contribute a substantial amount of organic matter in the form of dead leaves to the seepages.
2	Spruce Gulch Headwaters approximately 1,500 meters (1 mile) above its confluence with Cross Gulch. This station is located approximately 50 meters downstream from the seepage area. The spring at the headwaters of Spruce Gulch appears to be a sulfur spring since the odor of H_2S is very evident and the bottom of the stream appears to be covered with an unidentified fungus.
3	Corral Gulch Headwaters approximately 50 meters from Maverick Spring.
4	Water Gulch Headwaters approximately 1,500 meters (1 mile) above its confluence with Corral Gulch. This station is located about 50 meters below the seepage area.
5	Headwaters Area of Stake Springs Draw. This station is located in a marshy area approximately 8,000 meters (5 miles) above the confluence with Corral Gulch. This headwaters area consists of a series of seeps which form a marshy area with extensive aquatic vegetation.
6	The USGS gaging station on Box Elder Gulch, just after it enters Tract C-a.
7	The USGS gaging station on Corral Gulch near Water Gulch.
8	Box Elder Gulch (just after entering Tract C-a) approximately 1,200 meters (0.8 mile) below the USGS gaging station. This station is located about 50 meters below the seepage area.
9	Corral Gulch approximately 200 meters below its confluence with Water Gulch. This station is located on a small swift stream which has a gravel substrate.
10	The USGS gaging station on Dry Fork just as it enters Tract C-a.

Table 3-8-1. Continued

Station	Location
11	Dry Fork just after entering Tract C-a. This station is located about 50 meters below the USGS gaging station on Dry Fork.
12	Corral Gulch just after its confluence with Dry Fork Gulch. This station is located about 50 meters below the confluence.
13	The USGS gaging station on Corral Gulch just as it leaves Tract C-a.
14	Corral Gulch just after leaving Tract C-a. This station is located at a pond approximately 1,200 meters (0.8 mile) above 84 Ranch. Station 14 is located on a small pond which contains extensive mats of the aquatic plant *Zannichellia palustris*.
15	Corral Gulch approximately 100 meters upstream from its confluence with Stake Springs Draw.
16	The USGS gaging station on Stake Springs Draw.
17	Stake Springs Draw approximately 100 meters upstream of its confluence with Corral Gulch.
18	Yellow Creek approximately 100 meters downstream from the confluence of Corral Gulch and Stake Springs Draw.
19	Yellow Creek between the confluences of Duck Creek with Yellow Creek and Barcus Creek with Yellow Creek. This station is located at a pool which is choked with *Chara kieneri*.
20	Yellow Creek at the USGS gaging station near the White River.
21	Yellow Creek 100 meters above its confluence with the White River.
22	Yellow Creek 15 meters upstream from its confluence with the White River.
23	This station is located in a side channel of the White River about 800 meters (0.5 mile) above its confluence with Yellow Creek.

Table 3-8-1. Continued.

Station	
24,25,26	White River approximately 260 meters above the confluence of the White River with Yellow Creek. These stations are situated on a transect line which is perpendicular to the stream. Station 24 is located near the north shore of the White River; Station 25 is located in mid-stream; and Station 26 is located near the south shore.
27,28,29	These stations are located in the side channel at the confluence of the White River and Yellow Creek. Station 27 is situated about 30 meters above the confluence, Station 28 at the confluence, and Station 29 about 30 meters below the confluence.
30,31,32	These stations are located on the White River about 500 meters downstream from the confluence with Yellow Creek. Station 30 is located near the north shore of the White River; Station 31 is located in mid-stream; and Station 32 is located near the south shore.
33,34,35	These stations are located on the White River about 2,500 meters (1.5 miles) downstream from the confluence with Yellow Creek. Station 33 is located near the north shore of the White River; Station 34 is located in mid-stream; and Station 35 is located near the south shore.

grouped as follows: headwater stations (1-5); tract stations (6-18); Yellow Creek (lower) stations (19-22); and White River stations (23-35).

The schedule for the RBOSP Aquatic Baseline Program is presented in Table 3-8-2. As indicated in Table 3-8-2, sampling efforts are intensified during periods of increased biological activity.

At each sampling station all physical, chemical, and biological samples are taken on the same day in order to be assurred of comparable data. Whater chemistry data collected by the Water Resources Division of the USGS, at gaging stations on and near Tract C-a are presented in Section 3, Chapter 4, Hydrology. Additional water chemistry data collected during aquatic baseline studies are discussed herein and comparisons of these two sets of data have been made to further define the characteristics of the aquatic ecosystems in question.

Table 3-8-2. Schedule for RBOSP Aquatic Baseline Data Accumulation Program

RIO BLANCO OIL SHALE PROJECT	1974			1975												1976											
Month	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Period of Performance				X	X		X			X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
Study Schedule																											
Field Studies																											
Physical		X		X			X		X	X		X	X		X				X		X	X		X			
Water Chemistry		X		X			X		X	X		X	X		X				X		X	X		X			
Plankton		X		X			X		X	X		X	X		X				X		X	X		X			
Periphyton		X		X			X		X	X		X	X		X				X		X	X		X			
Primary Productivity																											
Analysis									X	X		X	X						X		X	X		X			
Benthos		X		X			X		X	X		X	X		X				X		X	X		X			
Macrophytes		X		X			X		X	X		X	X		X				X		X	X		X			
Fish		X		X			X		X	X		X	X		X				X		X	X					
Rare and Endangered Species		X		X			X		X	X		X	X		X				X		X	X		X			
Springs and Seepages		X		X	X		X		X	X		X	X		X		X		X		X	X		X			
Miscellaneous Studies							X		X		X		X		X		X										
Laboratory Analysis				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Statistical Analysis				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		

8.1 ABIOTIC

A. Physical Measurements

1. Objectives - The objectives of this aspect of the Aquatic Baseline Studies are to determine selected physical characteristics of the streams at each sampling site and to relate these characteristics with selected chemical and biological characteristics. The physical measurement program also includes those chemical parameters which are measured in conjunction with field sampling operations.

2. Methods - The following methods were used to determine selected physical characteristics at each sampling site. These determinations were made concurrently with the collection of chemical and biological samples. Stream velocity was measured with a Gurley flowmeter. The stream substrate was visually classified at each station at the same time as benthic samples were collected. Color and odor were determined for each sample by methods described by the American Public Health Association (APHA, 1971). The turbidity of each sample was determined with a Hach Photometric Turbidimeter. Field measurements of dissolved oxygen were taken with a portable dissolved oxygen meter or with the Alsterberg (Azide) modification of the Winkler Method (APHA, 1971).

Other parameters (and methods of measurement) which were determined in the field included pH (portable meter), specific conductance (portable meter), water temperature (thermister or equivalent), depth, width, and alkalinity (colorimetric; APHA, 1971).

4. Data Summary and Discussion - Table 3-8-3 includes the flow conditions for each sampling location and sampling period for the 1 yr period covered in this report and Table 3-8-4 includes stream velocities for each location and sampling period. Site specific data concerning the physical characteristics of the aquatic sampling sites for the 1 yr period are presented in Section 8.1A of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976).* The following discussion presents analyses and interpretations of those site specific data.

The aquatic habitats observed during the initial year of RBOSP Aquatic Baseline Studies included small shallow springs of less than 0.3 m (1 ft) in width and less than 2.5 cm (1 inch) in depth; small shallow ponds; and the major stream in the area, the White River which, can exceed 45 m (150 ft) in width and 1.2 m (4 ft) in depth.

Water temperatures in the study areas ranged from 0 to 27°C. During the winter, temperatures at the headwaters remained higher than those in the other streams, probably because the headwaters are spring-fed. Yellow Creek appeared to warm most rapidly in the spring and maintained the highest temperatures between June and August 1975. Water temperatures in the White River were above 20°C during the July - August sampling. It has been noted (Pennak, 1974) that streams in the Piceance Basin generally had higher mid-summer temperatures than other Rocky Mountain streams due to the relatively low elevations of the Piceance Basin. This appears to be the case in the Tract C-a study area.

DO concentrations varied seasonally, particularly in the small springs and streams on and near Tract C-a. Hynes (1970) indicated that such variations may be biologically induced. In the study area, dissolved oxygen (DO) concentrations ranged from 4.6 mg/l at Station 2 in October - November 1974 to 14.3 mg/l at Station 5 in April 1975 (the smell of sulfur near that site during the October - November 1974 sampling period suggested the inflow from sulfur springs). In Yellow Creek, the highest DO concentration was recorded in October 1974, the lowest in December 1974 - January 1975. Previous investigators (Everhart and May, 1973) reported low DO concentrations during

*NUS Annual Report

Table 3-8-3. Summary of flow conditions for RBOSP Aquatic Baseline Studies, October - November 1974 sampling period through August - September 1975 sampling period

Station	October - November	December - January	April	May - June	July - August	August - September
			Headwater			
1	F	Inacc.	F	F	F	F
2	F	Inacc.	F	F	F	F
3	F	F	F	F	F	F
4	F	F	F	F	F	F
5	F	F	F	F	F	F
			Tract			
6	D	D	D	F	D	D
7	F	F	F	F	F	F
8	F	F	F	F	F	F
9	F	F	F	F	F	F
10	D	D	D	D	D	D
11	D	D	D	D	D	D
12	D	D	D	D	D	F
13	F	F	F	F	F	F
14	F	F	F	F	F	F
15	D	Fr	D	D	F	D
16	D	D	D	D	D	D
17	D	D	D	D	F	F
18	D	Fr	D	D	F	D
			Yellow Creek			
19	F	F	F	F	F	F
20	F	F(IC)	F	F	F	F
21	F	F(IC)	F	F	F	F
22	F	F(IC)	F	F	F	F
			White River			
			Above Confluence with Yellow Creek			
23	F	F(IC)	F	F	F	F
24	F	F(IC)	F	F	F	F
25	F	F(IC)	F	F	F	F
26	F	F(IC)	F	F	F	F
27	F	F(IC)	F	F	F	F

Table 3-8-3. (Continued)

Station	October - November	December - January	April	May - June	July - August	August - September
		At Confluence with Yellow Creek				
28	F	F(IC)	F	F	F	F
29	F	F(IC)	F	F	F	F
		Below Confluence with Yellow Creek				
30	F	F(IC)	F	F	F	F
31	F	F(IC)	F	F	F	F
32	F	F(IC)	F	F	F	F
33	F	(IC)	F	F	F	F
34	F	F(IC)	F	F	F	F
35	F	F(IC)	F	F	F	F

F = Flowing
F(IC) = Flowing (Ice Covered)
(IC) = Ice Covered
D = Dry
Fr = Frozen
Inacc. = Inaccessible

Table 3-8-4. Summary of stream velocities observed during RBOSP Aquatic Baseline Studies, October - November 1974 through August - September 1975. (Results are expressed in feet per second, and where appropriate are given for bank side(s) and point of maximum velocity (m).)

Headwaters

Station	Sampling Period																	
	October - November			December - January[1]			April			May - June			July - August			August - September		
	s	m	s	s	m	s	s	m	s	s	m	s	s	m	s	s	m	s
1		0.5						0.1(1/sec)			1.5			0.4			<0.1	
2		1.4						0.8			2.5			1.3			0.9	
3		0.5			0.3			0.4			0.9			1.3			1.3	
4	0.9;		0.04		0.7			0.5			1.4			1.5			2.0	
5		1.3			0.4			0.9;0.3			1.4			0.4			0.9	

[1]Stations 1, 2 were dry, frozen solid, or inaccessible due to snow accumulation at the time of sampling.

Table 3-8-4. Continued.

Tract

Station	Sampling Period																	
	October - November[1]			December - January[2]			April[3]			May - June[4]			July - August[5]			August - September[6]		
	s	m	s	s	m	s	s	m	s	s	m	s	s	m	s	s	m	s
6										3.5;2.0								
7	1.0;		0.5					0.5		2.5				1.5			2.0	
8		1.0			0.9			1.0		3.2;1.8			1.7;2.0				1.3	
9		1.5			0.7			1.7		1.7				2.1			1.9	
12																	1.3	
13	0.5;0.5;0.6			0.2;0.7;0.6				1.0		1.7				2.0			1.1	
14		1.3			2.2			0.5		0.0				0.0			1.0	
15														0.8				
17														0.4			0.0	
18														0.8				

[1]Stations 6, 10-12 and 15-18 were dry at the time of sampling.

[2]Stations 6, 7, 10-12, 15-18 were frozen solid or inaccessible at the time of sampling.

[3]Stations 6, 10-12 and 16 were dry at the time of sampling.

[4]Stations 10-12 and 15-18 were dry at the time of sampling.

[5]Stations 6, 10-12 and 16 were dry at the time of sampling.

[6]Stations 6, 10-11, 15-16 and 18 were dry at the time of sampling.

Table 3-8-4. Continued.

Yellow Creek

Station	Sampling Period																	
	October - November			December - January			April			May - June			July - August			August - September		
	s	m	s	s	m	s	s	m	s	s	m	s	s	m	s	s	m	s
19		2.8		3.0;		1.0			2.4		1.8			1.8			1.2	
20		1.7				1.9	1.6;		1.0		1.3			1.4			0.7	
21	0.8;	1.4;	0.2			0.3	1.3;		1.7		0.8			0.8			1.2	
22	1.0;	0.8;	0.2			1.6	1.3;		0.4		0.7			0.7			1.5	

Table 3-8-4. Continued.

White River

Station	October - November (s m s)	December - January (s m s)	April (s m s)	May - June (s m s)	July - August (s m s)	August - September (s m s)
Above Confluence with Yellow Creek						
23	2.9;3.3;1.4	1.4	1.2;3.5	2.1;0.2	1.0;2.9	1.0;1.9;0.1
24	1.7;3.2;1.2	2.2; 3.2	1.7;2.0;3.8	4.4;3.0	2.4;2.2	0.9;1.6;2.6
25	1.7;3.2;1.2	2.2; 3.2	3.8;3.6;3.0	7.5	2.8;2.9	2.6;3.3;2.7
26	1.7;3.2;1.2	2.2; 3.2	3.0;2.8;2.5	4.6;3.0	1.9;2.9	2.7;2.3;1.0
27	0.4;0.4;0.6	ND	0.4;1.2	1.6;1.2	0.4;1.2	0.1;0.9;0.3
At Confluence with Yellow Creek						
28	1.0;1.4;0.5	ND	1.9;1.9	3.3;0.8	1.0;1.3	0.2;1.2;1.0
29	3.4;2.3	1.3;3.6;2.3	1.9;3.6	5.8;3.1	2.1;3.1	2.3;2.5;1.3
Below Confluence with Yellow Creek						
30	0.8;2.8;1.9	1.3;3.6;2.3	1.3;2.2;2.2	5.3	2.7;3.1	1.2;2.5;1.3
31	0.8;2.8;1.9	1.3;3.6;2.3	2.3;2.5;2.4	6.7	2.4;3.1	2.3;2.3;2.7
32	0.8;2.8;1.9	1.3;3.6;2.3	2.4;2.0;1.0	3.9;1.5	1.7;2.9	2.7;2.3;0.6
33	0.3;1.4;1.0	0.5	1.4;2.5	3.5	1.0;2.8	0.5;0.5;0.3
34	2.7;3.0;2.0	0.5	3.5;2.5	3.5	1.0;1.7	1.4;3.6
35	3.4;4.3;2.5	2.3;2.9;2.7	4.6;2.7	4.0;3.1	1.7;2.9	1.7;5.2;2.6

ND = Not Determined

November and December. The occurrence of low DO in the winter months probably resulted from the death and decay of filamentous algae in Yellow Creek due to the advent of ice cover and the decreased light intensity under the ice cover. In the White River, on the other hand, highest DO concentrations occurred in December 1974 - January 1975 and the lowest concentrations were recorded during July - August 1975. Because of the relatively large size, swift currents, and great turbulence of the White River, seasonal variations in DO concentrations are probably more closely related to water temperature than to changes caused by biological activity.

The streams in the study area are very alkaline, as indicated by the ranges of total alkalinity (113 to 1,858 mg/l) and pH (7.3 to 8.7). Yellow Creek (particularly Stations 20 - 22) had the highest alkalinities of any of the streams studied. Alkalinities in Yellow Creek consistently exceeded 1,000 mg/l, whereas alkalinities in the White River ranged from 108 to 486 mg/l. Seasonal variations in alkalinity were particularly evident in the White River where lowest alkalinities were recorded during the May - June 1975 sampling (a period of very high flows) and highest alkalinities were observed during the July - August 1975 sampling. The range of alkalinities observed in the White River during the initial year of RBOSP Aquatic Baseline Studies was somewhat greater than those observed by previous investigators (Everhart and May, 1974; Pennak, 1974); the range in Yellow Creek was somewhat less. Alkalinity in natural waters is due primarily to the presence of the salts of weak acids. Bicarbonates generally constitute the major form of alkalinity since large quantities of bicarbonates are formed from the action of carbon dioxide upon basic materials in the soil. Data from the Water Resources Division of the USGS (Section 3, Chapter 4, Hydrology) indicate that bicarbonates are, in fact, the major contributors to high alkalinities in waters of the area. Certainly, all of the streams considered in the RBOSP Aquatic Baseline Studies contain alkalinities well in excess of the 20 mg/l suggested as necessary for biologically productive waters by FWPCA (1968).

Specific conductance was very high in Yellow Creek, particularly at Stations 20 - 22, and was lowest in the White River (Figure 3-8-2). In general, lowest

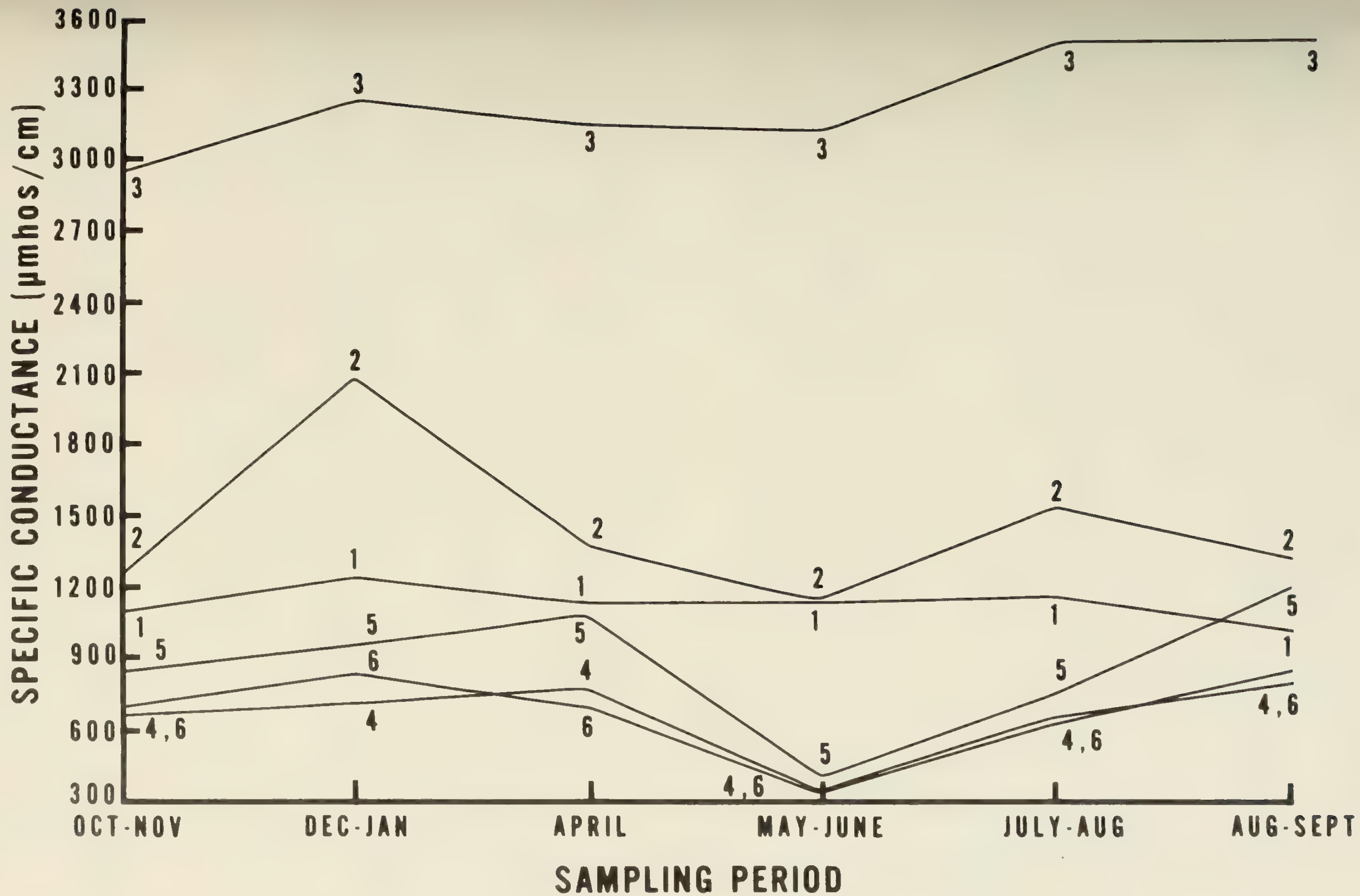

Figure 3-8-2. Mean specific conductance for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater Group; 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River (above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

conductivities were recorded during periods of high flow and the highest conductivities during periods of low flow. Pennak (1974) suggested that the high concentrations of dissolved materials in streams of the Piceance Basin is related to the relatively soluble substrates which occur there.

Turbidities of streams included in the RBOSP Aquatic Baseline Studies were generally highest in the spring and lowest in the late fall and early winter (Figure 3-8-3). Local events, such as the movement of vehicles and animals through the streams, variations in groundwater flow and rain showers, often created high turbidities of short duration.

Physical and chemical data from the comprehensive surface water monitoring program being conducted by the Water Resources Division of the USGS are presented in Section 3, Chapter 4, Hydrology. Comparisons of WRD data with chemical data collected during aquatic baseline studies are discussed in the following section, Section 8.1B, Chemical measurements.

In summary, aquatic habitats considered in RBOSP Aquatic Baseline Studies program included small shallow springs and streams, small ponds, and the relatively large and turbulent White River. Water temperatures were generally high during the summer and dissolved oxygen concentrations fluctuated seasonally and among sampling stations. Variations in DO concentrations in the small springs and streams and in Yellow Creek probably reflected variations in biological activity whereas seasonal variations in the DO of the White River were probably more closely related to variations in water temperature. Due to the relatively soluble alkaline substrates of the region, waters were very alkaline with high conductivities. Turbidities varied with local conditions but were generally highest during the spring and lowest during late fall and early winter.

The biological importance of temperature, turbidity, alkalinity, suspended and dissolved solids, dissolved oxygen, and current velocity were evident during the initial year of baseline studies. These important parameters should be included in aquatic studies during the monitoring phase.

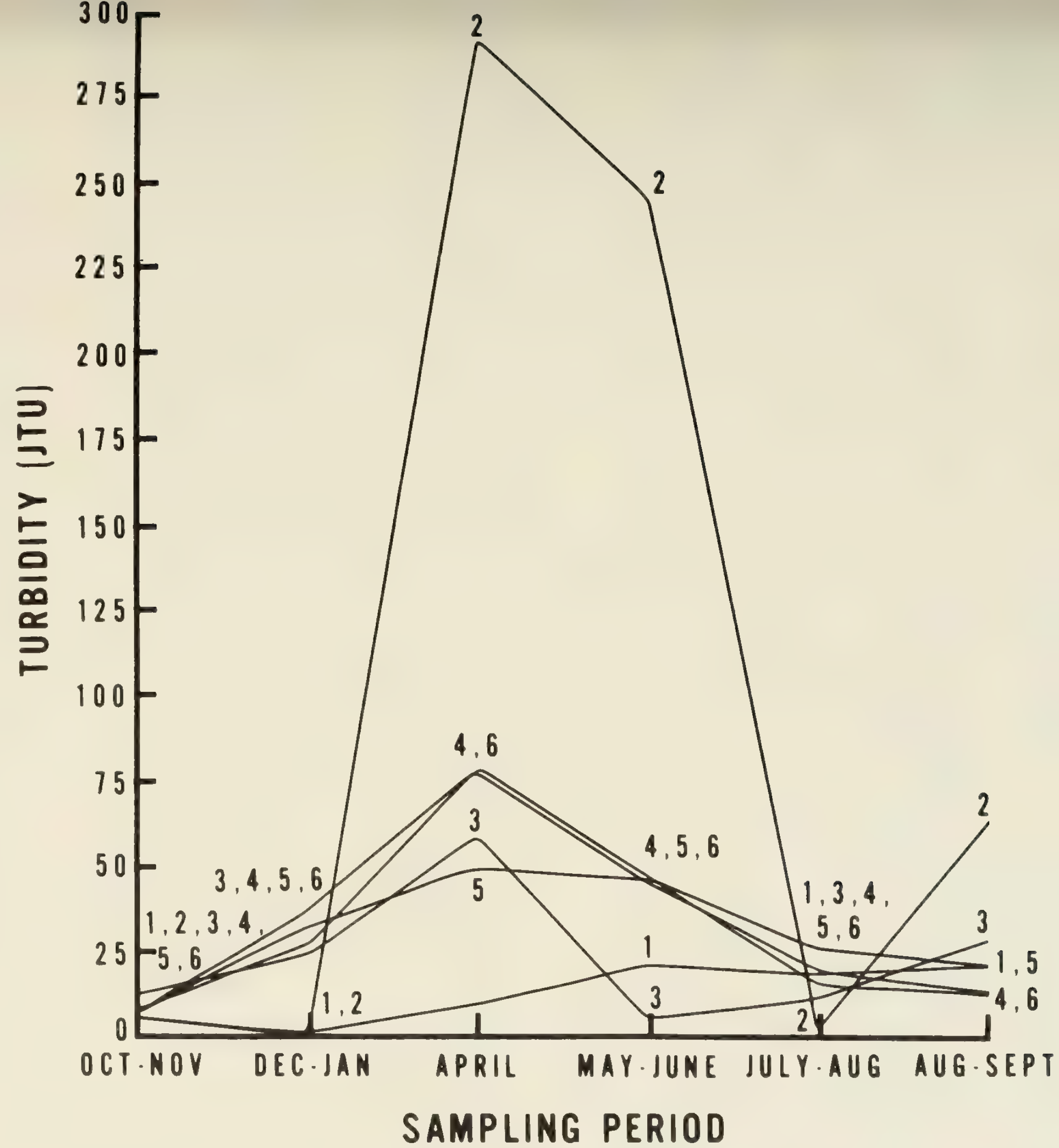

Figure 3-8-3. Mean turbidities for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

B. Chemical Measurements

1. Objectives - The objectives of this aspect of the Aquatic Baseline Studies are to make determinations of certain chemical characteristics which may be of particular biological significance to the streams and to relate these chemical data to physical and biological data collected at the same time.

2. Methods - Duplicate samples were collected at each sampling station. Chemical determinations included: ammonia nitrogen, dissolved calcium, dissolved chloride, total hardness, dissolved magnesium, Kjeldahl nitrogen, dissolved nitrate, dissolved nitrite, dissolved orthophosphate, total phosphate, dissolved potassium, dissolved silica, dissolved sodium, dissolved sulfate, dissolved organic carbon, total organic carbon, suspended solids, and total dissolved solids. Other chemical measurements, made in conjunction with field sampling programs, are discussed in Section 8.1A.

Table 3-8-5 presents the analytical methods, limits of detection, and methods of sample preservation for the aforementioned analyses. The analytical methods for water listed in Table 3-8-5 are essentially those listed in the Federal Register, Volume 38, Number 199, October 16, 1973.

3. Data Summary and Discussion - Site specific data concerning the chemical characteristics of aquatic sampling locations for the 1 yr period are included in Section 8.1B of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976). The following discussion presents analyses and interpretations of those specific data.

As indicated in Figure 3-8-4, the waters studied in RBOSP Aquatic Baseline Studies ranged in hardness from hard (150 to 300 mg/l $CaCO_3$) to very hard (above 300 mg/l $CaCO_3$), according to the classification of Sawyer and McCarty (1967). Calcium and magnesium, the alkaline earth cations primarily responsible for hardness in most waters, were present in relatively high concentrations in all waters studied in the RBOSP Aquatic Baseline Studies (Figures 3-8-5 and 3-8-6). However, calcium and magnasium carbonates did not account for all of the hardness

Table 3-8-5. Water and sediment chemistry, analytical laboratory methodology for RBOSP Aquatic Baseline Studies.

Parameter	Measurement Methodology[2]	Detection Limit (ppm)[3]	Sample Preservation
	WATER CHEMISTRY		
Alkalinity, total[1]	Colorimetric	2	None required
Ammonia nitrogen	Electrode	0.10	$HgCl_2$ + Refrigeration
Calcium, dissolved	Atomic absorption	0.02	HCl
Chloride, dissolved	Potentiometric	0.4	None required
Hardness, total	EDTA Titration	2	HCl
Magnesium, dissolved	Atomic absorption	0.005	HCl
Nitrogen, total Kjeldahl	Kjeldahl digestion - electrode	0.10	$HgCl_2$ + Refrigeration
Nitrate, dissolved	Brucine	0.2	$HgCl_2$ + Refrigeration
Nitrite, dissolved	Diazotization	0.01	$HgCl_2$ + Refrigeration
Phosphate, ortho (dissolved)	Ammonium molybdate - potassium antimonyl tartrate	0.01	$HgCl_2$ + Refrigeration
Phosphate, total	Same as orthophosphate	0.01	$HgCl_2$ + Refrigeration
Potassium, dissolved	Atomic absorption	0.1	HCl
Silica, dissolved	Molybdosilicate	0.04	None
Sodium, dissolved	Atomic absorption	0.005	HCl
Sulfate, dissolved	Gravimetric	3	HCl
Carbon, dissolved organic	Beckman Analyzer	2	Refrigeration
Carbon, total organic	Beckman Analyzer	2	Refrigeration
Solids, suspended	Filtration	1	Refrigeration
Solids, total dissolved	Filtration and evaporation	1	Refrigeration

[1] Field

[2] Methods are those specified in the Federal Register, Vol. 38, No. 199, Oct. 16, 1973, except for use of specific ion electrode.

[3] For water samples, this detection limit is the minimum concentration which will be reported on natural and treated water samples (99.99% H_2O) with the indicated method and using a sample of defined size.

Table 3-8-5. (Continued)

Parameter	Measurement Methodology	Detection Limit (ppm)[5]	Sample Preservation
	SEDIMENT CHEMISTRY[4]		
Arsenic	Extraction and Colorimetric	1	Refrigeration
Aluminum	Extraction and Atomic absorption	10	Refrigeration
Herbicide	Gas Chromatography	100 ppb	Refrigeration
Lead	Extraction and Atomic absorption	5	Refrigeration
Mercury	Extraction and Atomic absorption	0.02	Refrigeration
Nitrogen, total Kjeldahl	Kjeldahl digestion - Electrode	25	Refrigeration
Phosphate, total	Persulfate digestion	3	Refrigeration
Solids, total volatile	Filtration, evaporation, volatilization	10	Refrigeration
Zinc	Extraction and Atomic absorption	2	Refrigeration

[4]Methods used are essentially those in the "Chemistry Laboratory Manual, Bottom Sediments" compiled by Great Lakes Region, Committee on Analytical Methods, EPA, 1969.

[5]Detection limits vary with sample size.

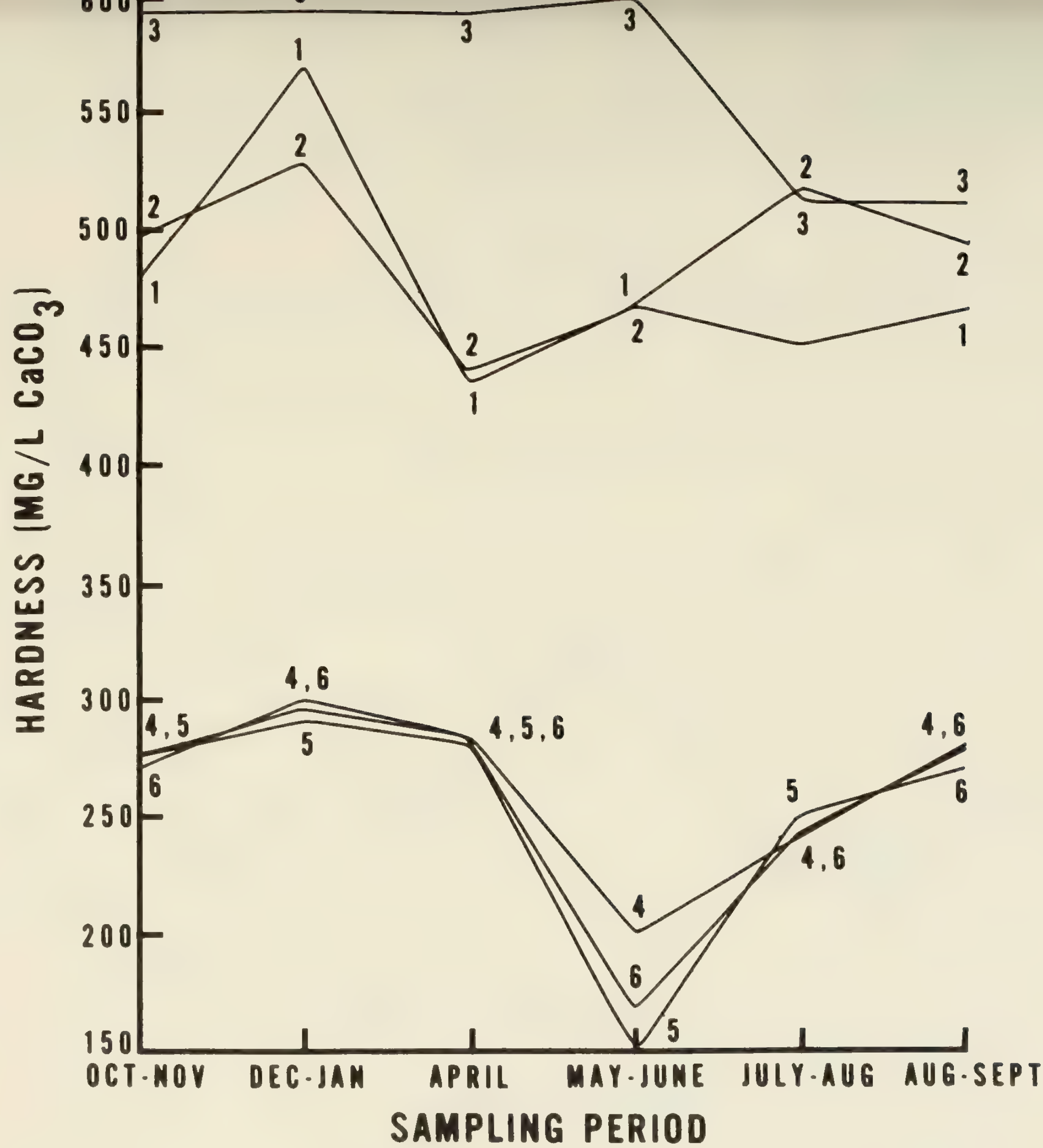

Figure 3-8-4. Mean hardness concentrations for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

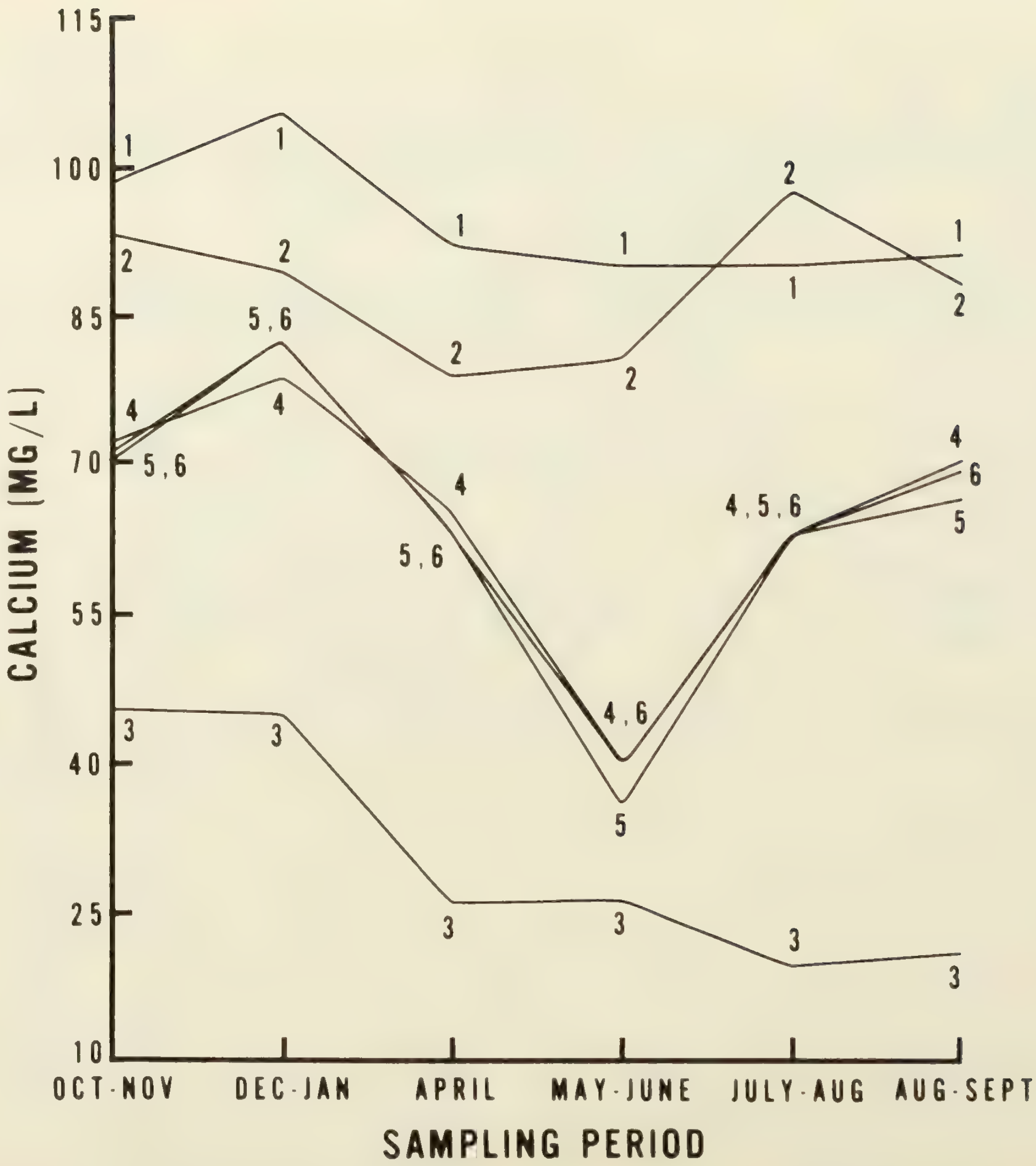

Figure 3-8-5. Mean calcium concentrations for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

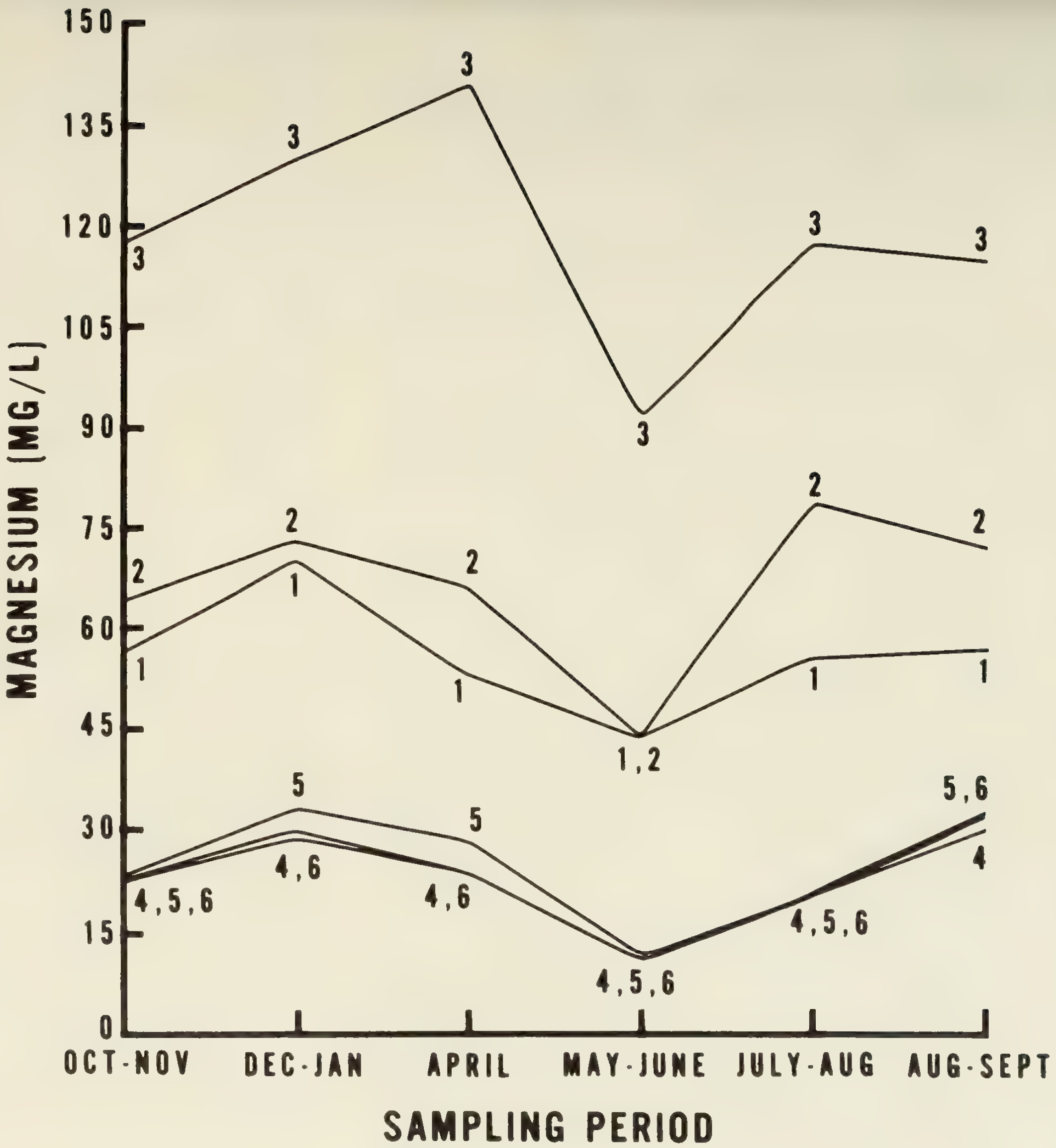

Figure 3-8-6. Mean magnesium concentrations for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

According to Brown et al. (1970), the fraction of hardness which is equivalent to the alkalinity is the carbonate hardness, while any excess is non-carbonate hardness which is due to the salts of alkaline earth metals other than carbonates and bicarbonates. In the present study area, waters generally contained both carbonate and non-carbonate hardness.

Pennak (1974) observed that, in many streams of the Piceance Creek Basin, magnesium is more abundant than calcium, a reverse of the situation expected in most streams. This phenomenon was observed only in Yellow Creek during the current RBOSP studies. Seasonal variations in the concentrations of calcium, magnesium and hardness were particularly evident during the spring when high flows resulted in dilution of calcium, magnesium, and hardness concentrations, except in lower Yellow Creek. The hardest waters in the study area occurred in Yellow Creek and, in particular, at Station 19, a pond fed by a saline spring. The ranges of calcium and magnesium concentrations observed in the White River and Yellow Creek during RBOSP Aquatic Baseline Studies were similar to that observed by Everhart and May (1973). The higher concentrations of calcium which were reported by Pennak (1974) for Yellow Creek and the White River can probably be attributed to differences in analytical methodology.

Chloride concentrations were higher in Yellow Creek than in other waters during the initial year of aquatic studies, and were somewhat higher in the White River than in either the headwater or tract areas (Figure 3-8-7). Seasonal variations in chloride concentrations were most noticeable in Yellow Creek and especially in the White River, as the chloride concentrations decreased during the period of high spring flows. The 170 mg/l of chloride suggested by Hart et al. (1945, cited in McKee and Wolf, 1963) as the limit below which freshwater fish do well, was approached or exceeded only in Yellow Creek. The fact that chloride concentrations in the White River were generally higher than in either the tract or headwater areas probably resulted from the inflow of a number of saline streams as well as from irrigation return and groundwater. Pennak (1974) noted that the inflow of the saline waters of Piceance Creek produced marked changes in the salinity of the White River. The ranges of chloride concentrations in the White River and Yellow Creek during ranges of chloride concentrations in the White

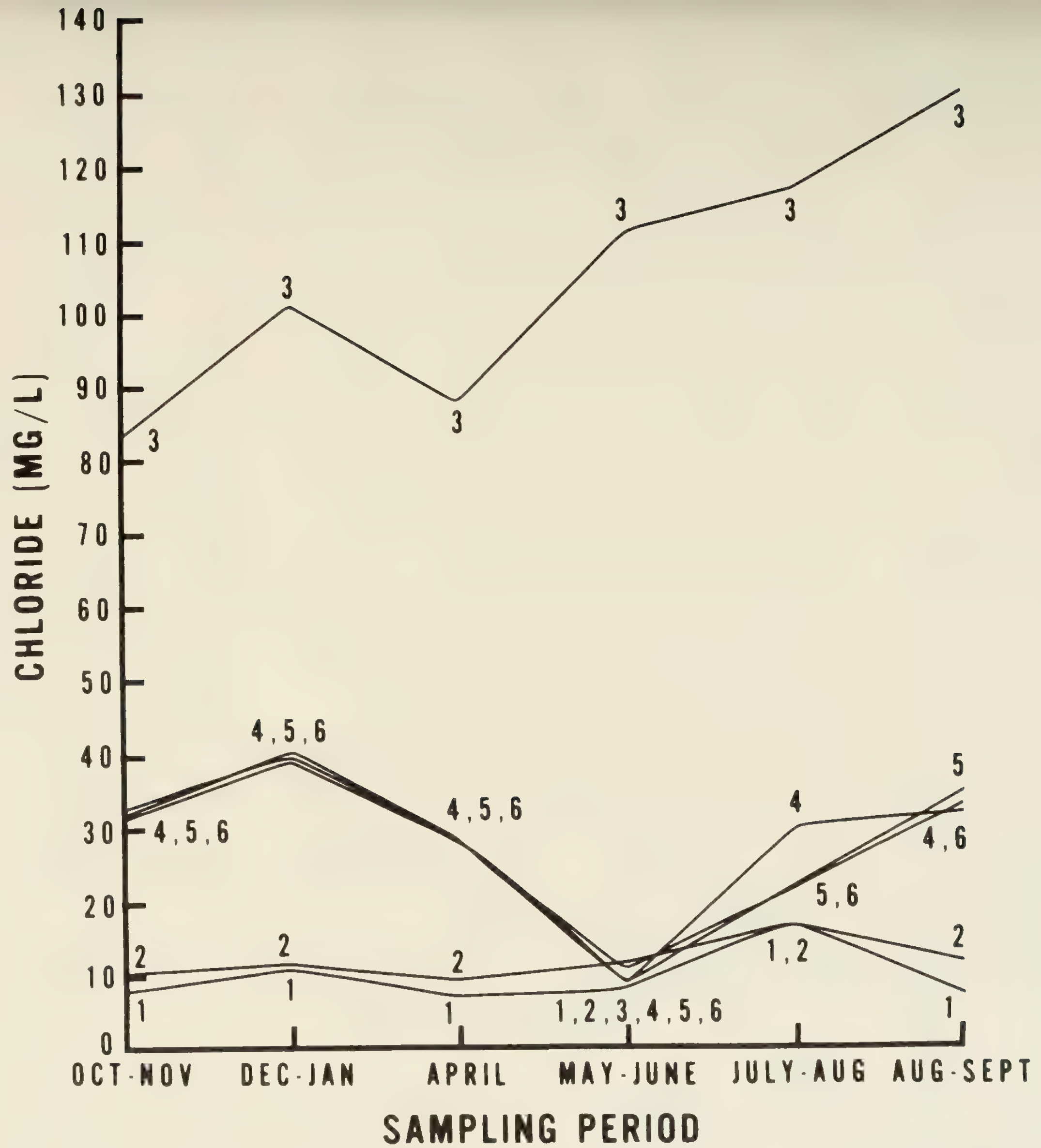

Figure 3-8-7. Mean chloride concentrations for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

River and Yellow Creek during RBOSP Aquatic Baseline Studies were generally similar to those reported by Everhart and May (1973) and Pennak (1974), although the chloride concentrations in Yellow Creek were lower during the present studies than reported previously. This is probably due to the inclusion of Station 19 in the RBOSP studies; Everhart and May and Pennak did not study Station 19. Chloride concentrations were generally lower at Station 19 than at the other Yellow Creek stations.

Sodium concentrations were very high in Yellow Creek and were higher there than in any of the other waters sampled (Figure 3-8-8). Sodium concentrations were generally somewhat higher at Station 28 and 29 in the White River at its confluence with Yellow Creek than at other White River stations, suggesting at least a localized effect on the salinity of the White River (Figure 3-8-8). Sodium concentrations in Yellow Creek always fell within the 500 - 1,000 mg/l range reported by McKee and Wolf (1963) as the threshold for toxicity to fish. In Yellow Creek, the range of sodium concentrations observed during RBOSP Aquatic Baseline Studies was between those reported by Everhart and May (1973) and Pennak (1974), whereas, the range of sodium concentrations observed in the White River during the present studies was slightly greater than that observed during earlier investigations.

The concentration of sulfate was relatively high in all waters, but it was much higher in Yellow Creek than in any other area (Figure 3-8-9). Seasonal variations, in sulfate concentrations were particularly noticeable in the headwaters and in the White River, where increased flows during the spring produced a dilution of sulfate concentrations. The inflow of high sulfate concentrations from Yellow Creek produced slightly higher sulfate concentrations in the White River at and below the confluence (Figure 3-8-9). The ranges of sulfate concentrations (expressed as sulfur) recorded in Yellow Creek and the White River during RBOSP Aquatic Baseline Studies were generally similar to those reported by Everhart and May (1973) and Pennak (1974).

The concentrations of dissolved solids was generally high (greater than 400 mg/l) in all waters of the study area, and was particularly high in Yellow Creek

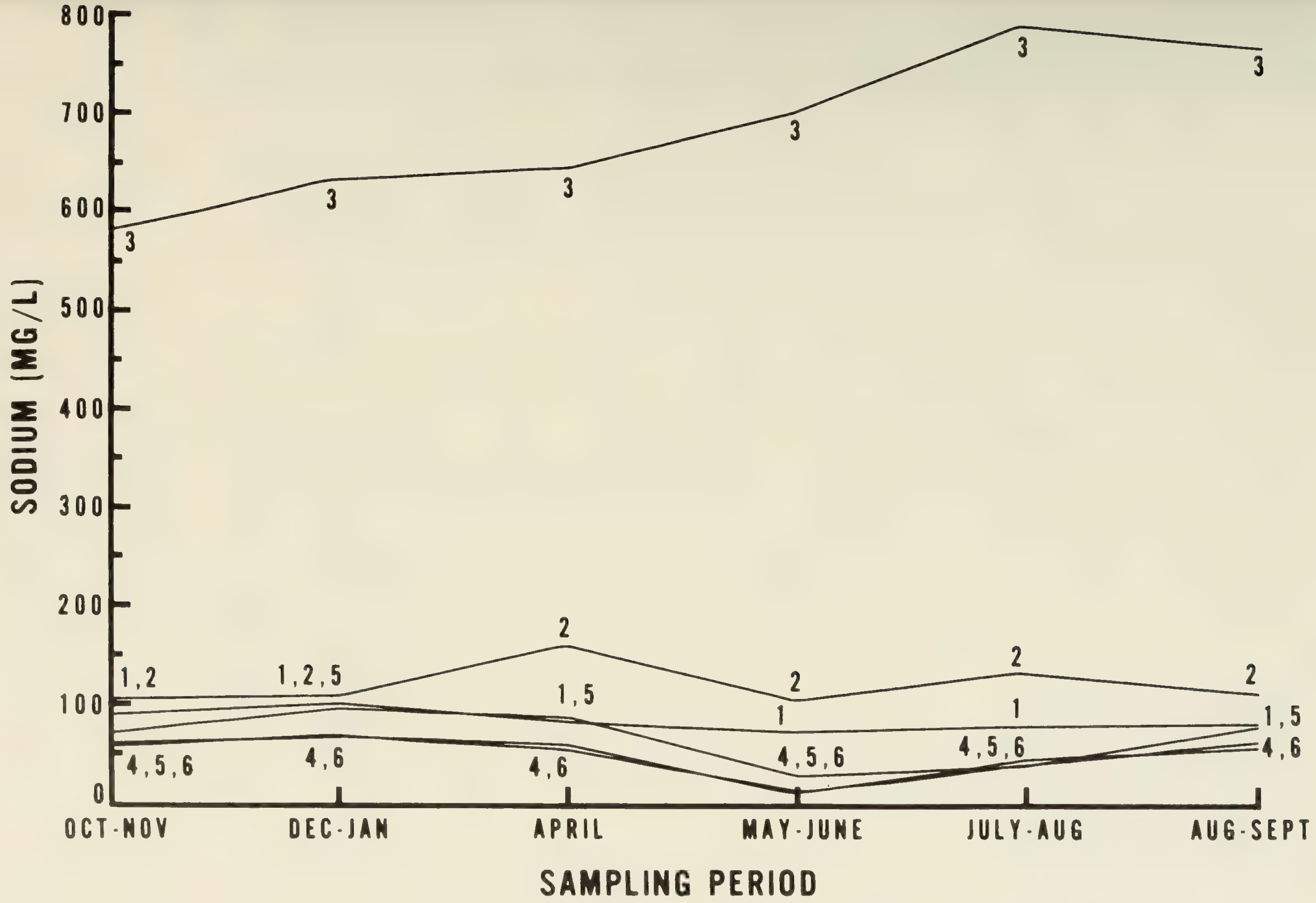

Figure 3-8-8. Mean sodium concentrations for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

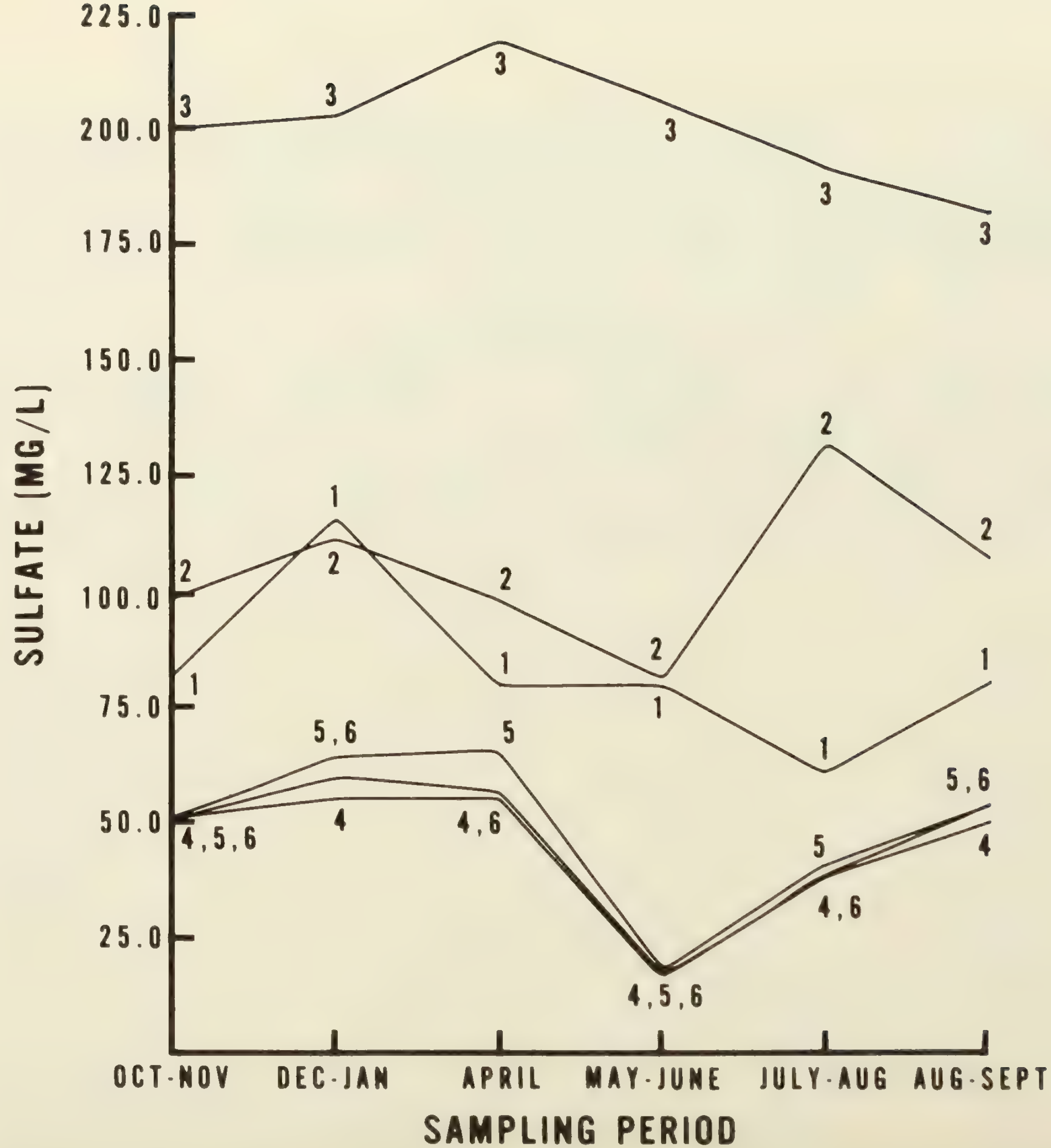

Figure 3-8-9. Mean sulfate concentrations for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

(greater than 2,000 mg/l) (Figure 3-8-10). Specific conductance and dissolved solids concentrations were greatest in Yellow Creek and lowest in the White River and appeared to be related to each other in a manner similar to that suggested by Hem (1959). The major contributors to dissolved solids (carbonates, bicarbonates, sulfates and chlorides) were all found in highest concentrations in Yellow Creek and in lowest concentrations in the White River. Pennak (1974) noted that streams of the Piceance Basin carry large quantities of dissolved solids and are thus considerably different chemically from typical granitic Colorado mountain streams.

Suspended solids concentrations were generally highest at the tract stations and lowest in the headwaters. In most of the study areas, suspended solids concentrations were highest during the spring runoff.

The quantity of organic carbon (both total and dissolved) was somewhat higher at the tract and Yellow Creek sites than in the headwaters or White River, probably because of greater inflow of allochthonous organic matter. At times, the quantity of dissolved organic carbon was higher than that of total organic carbon. The reason for this is probably related to analytical variability.

Nitrate and Kjeldahl nitrogen were the most abundant forms of nitrogen found in waters of the study area. Both forms of nitrogen were generally found in higher concentrations in the tract and headwater regions than elsewhere, although the highest nitrate concentrations were recorded in Yellow Creek during the winter of 1974 (Figure 3-8-11). Hynes (1970) noted that nitrate levels in streams have never been documented as being limiting for plant growth. This appears to be the case in the streams considered in the present studies.

The concentrations of orthophosphate and total phosphate varied considerably among sampling locations and sampling periods. Both constituents were generally present in low concentrations (Figure 3-8-12 and 3-8-13) although the concentrations of orthophosphate were generally higher than the 0.015 mg/l suggested by the Federal Water Pollution Control Administration (1968) as limiting to the growth of algae.

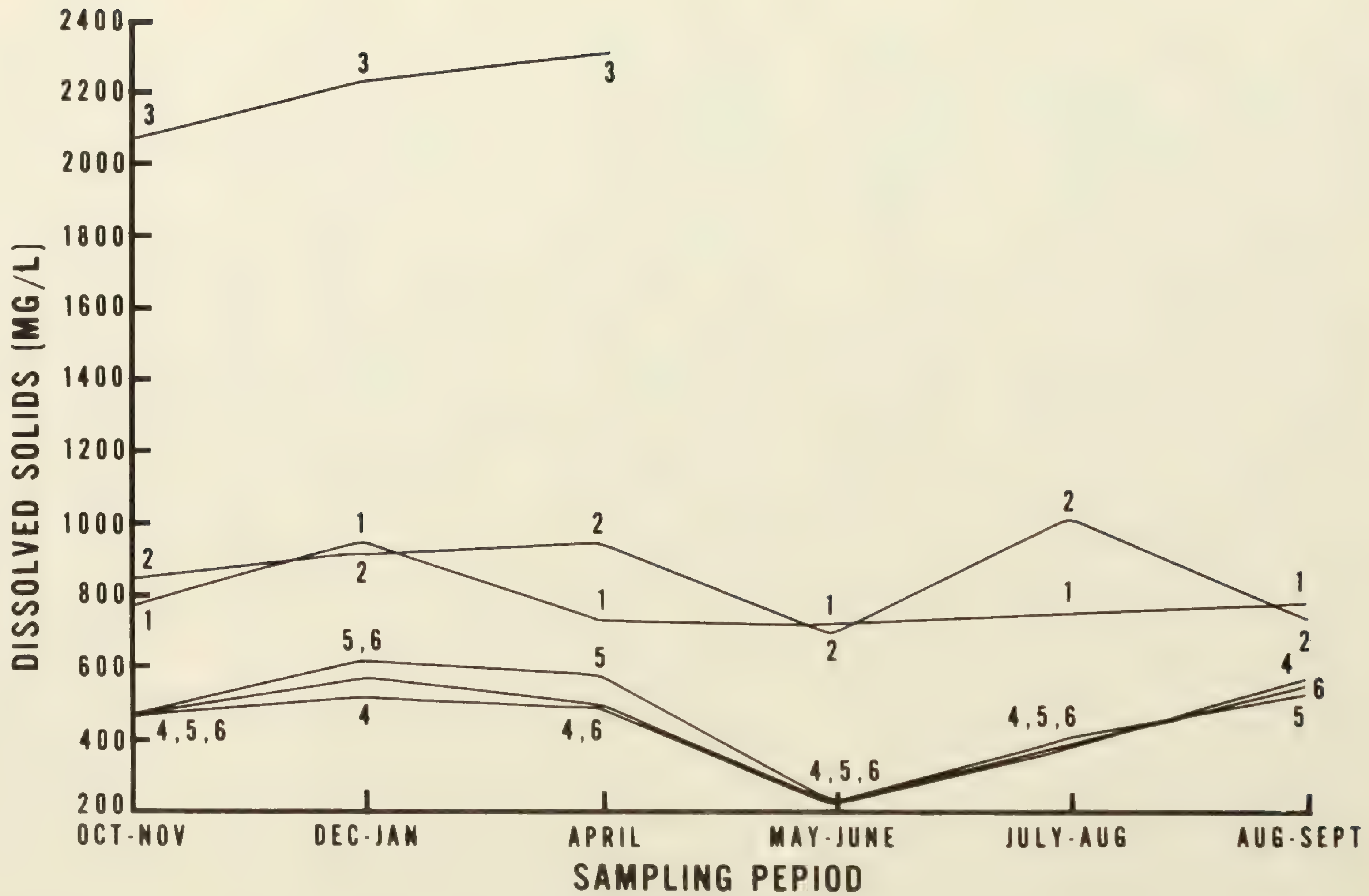

Figure 3-8-10. Mean dissolved solids concentrations for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

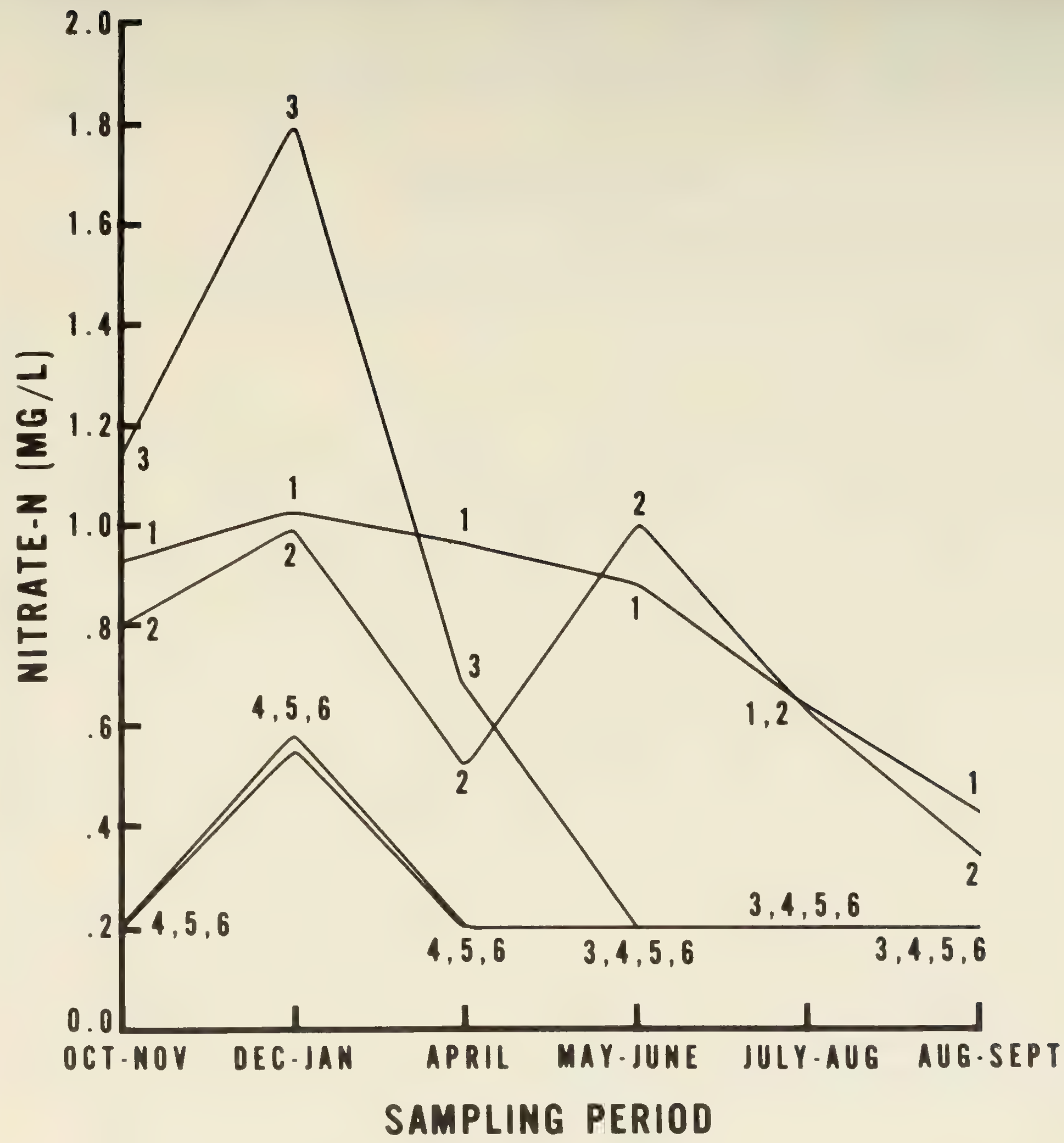

Figure 3-8-11. Mean nitrate (N) concentrations for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

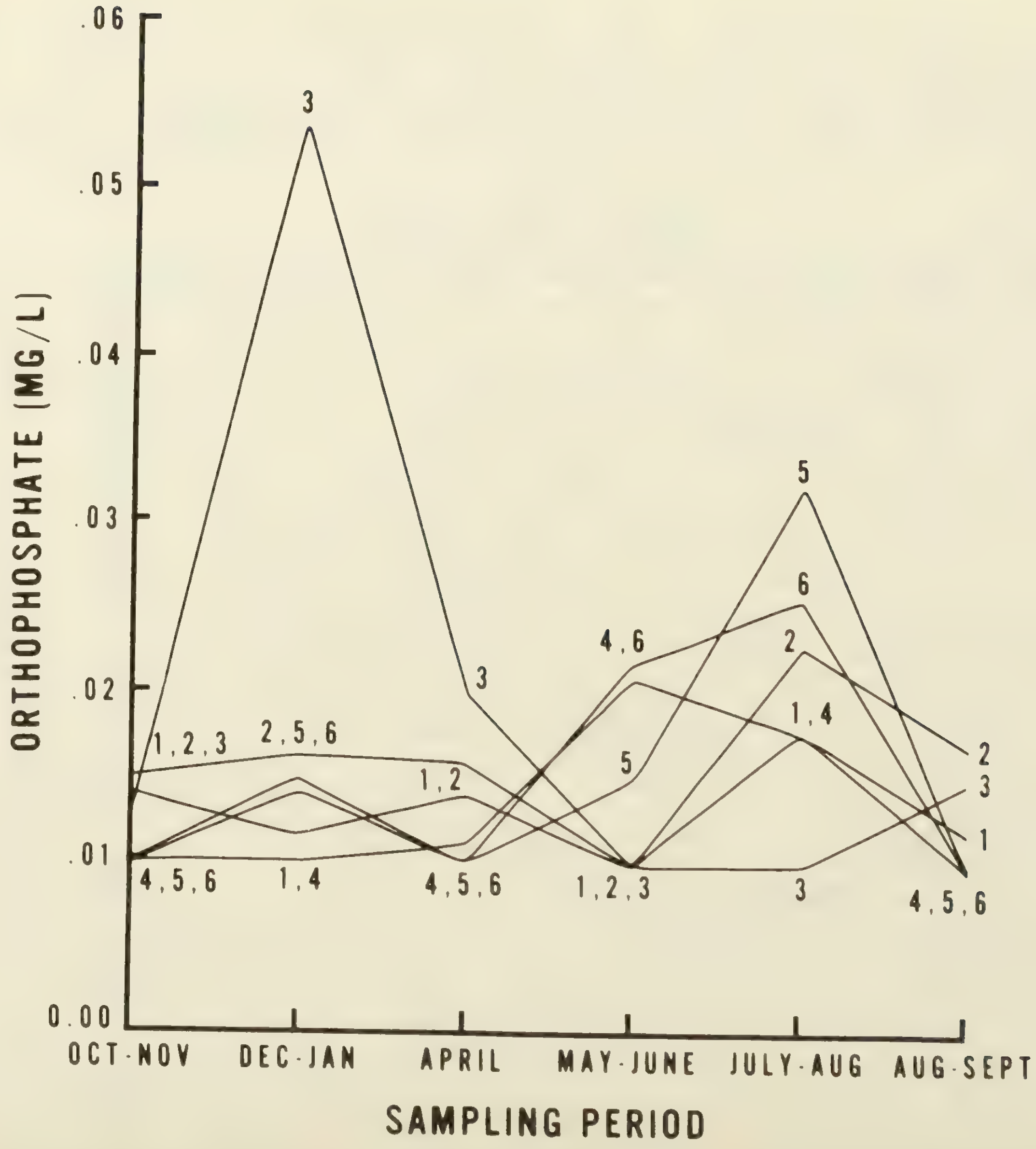

Figure 3-8-12. Mean orthophosphate (P) concentrations for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

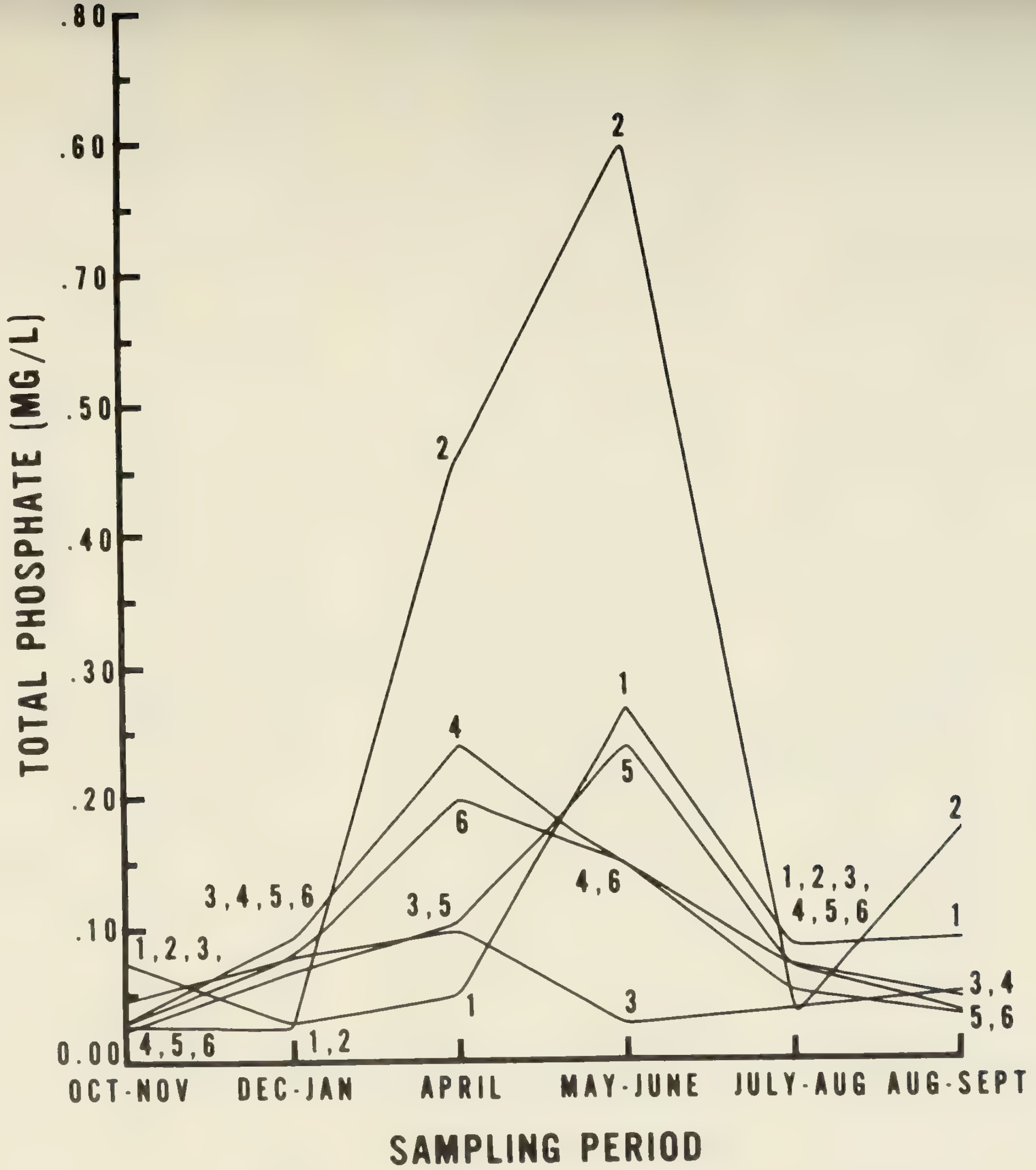

Figure 3-8-13. Mean total phosphate (P) concentrations for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

Potassium occurred in considerably higher concentrations in Yellow Creek than elsewhere (Figure 3-8-14), but the potassium concentrations in Yellow Creek were well below the 50 to 300 mg/l toxicity threshold suggested by McKee and Wolf (1963). The concentrations of pottassium in all waters considered in the present studies were higher than those which would be considered limiting for algal growth.

Silica concentrations were generally highest in waters of the headwater and tract areas and lowest in Yellow Creek (Figure 3-8-15). Silica levels were generally highest in the winter sampling and were high enough so as not to limit the growth of diatoms in any of the waters being studied.

In Section 3, Chapter 4, Hydrology, a summary of water chemistry data collected by the Water Resources Division of the U. S. Geological Survey and a summary of water chemistry data collected as part of the Aquatic Baseline Studies have been presented for those specific sites and parameters which are common to both programs. Comparison of WRD and Aquatic Baseline data (for those parameters and sites where such comparisons are meaningful) suggests close aggreement, considering that samples were collected at different times, and, in some cases, different analytical methods were employed.

In summary, waters included in the RBOSP Aquatic Baseline Studies ranged from hard to very hard, with high calcium and magnesium concentrations in all waters. The hardest waters in the study area occurred in Yellow Creek. Yellow Creek also contained higher chloride, sodium, sulfate, dissolved solids, nitrate and potassium concentrations than the headwater, tract or White River study areas. The inflow of saline Yellow Creek waters to the White River produced slightly higher concentrations of sodium, sulfate and dissolved solids in the area of the confluence than in other areas of the White River. Sodium concentrations in Yellow Creek consistently fell within the range reported as the threshold for toxicity to fish. While the concentration of dissolved solids was generally high (greater than 400 mg/l) in all waters of the study area, it was particularly high (greater than 2,000 mg/l) in Yellow Creek. Suspended solids

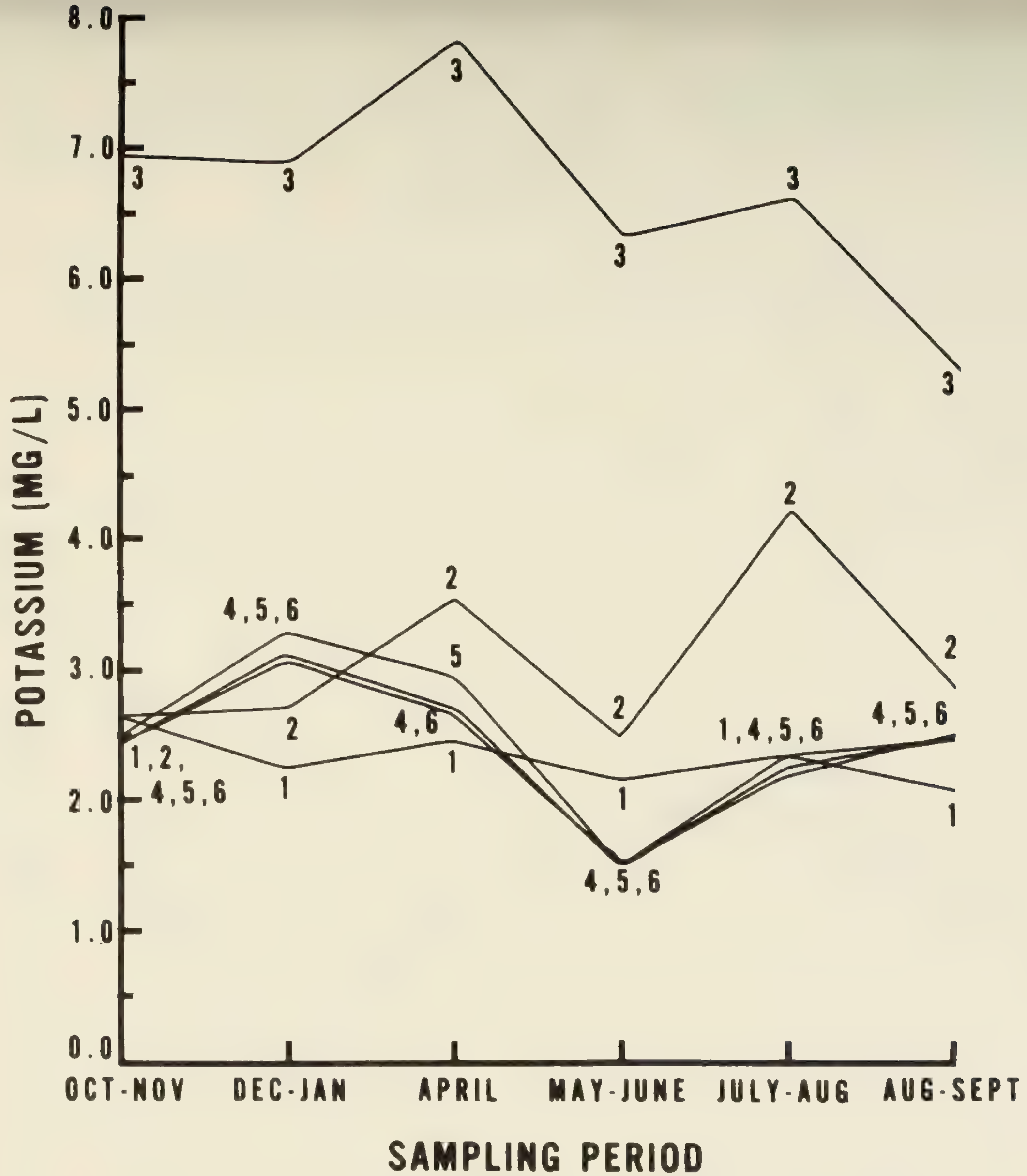

Figure 3-8-14. Mean potassium concentrations for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

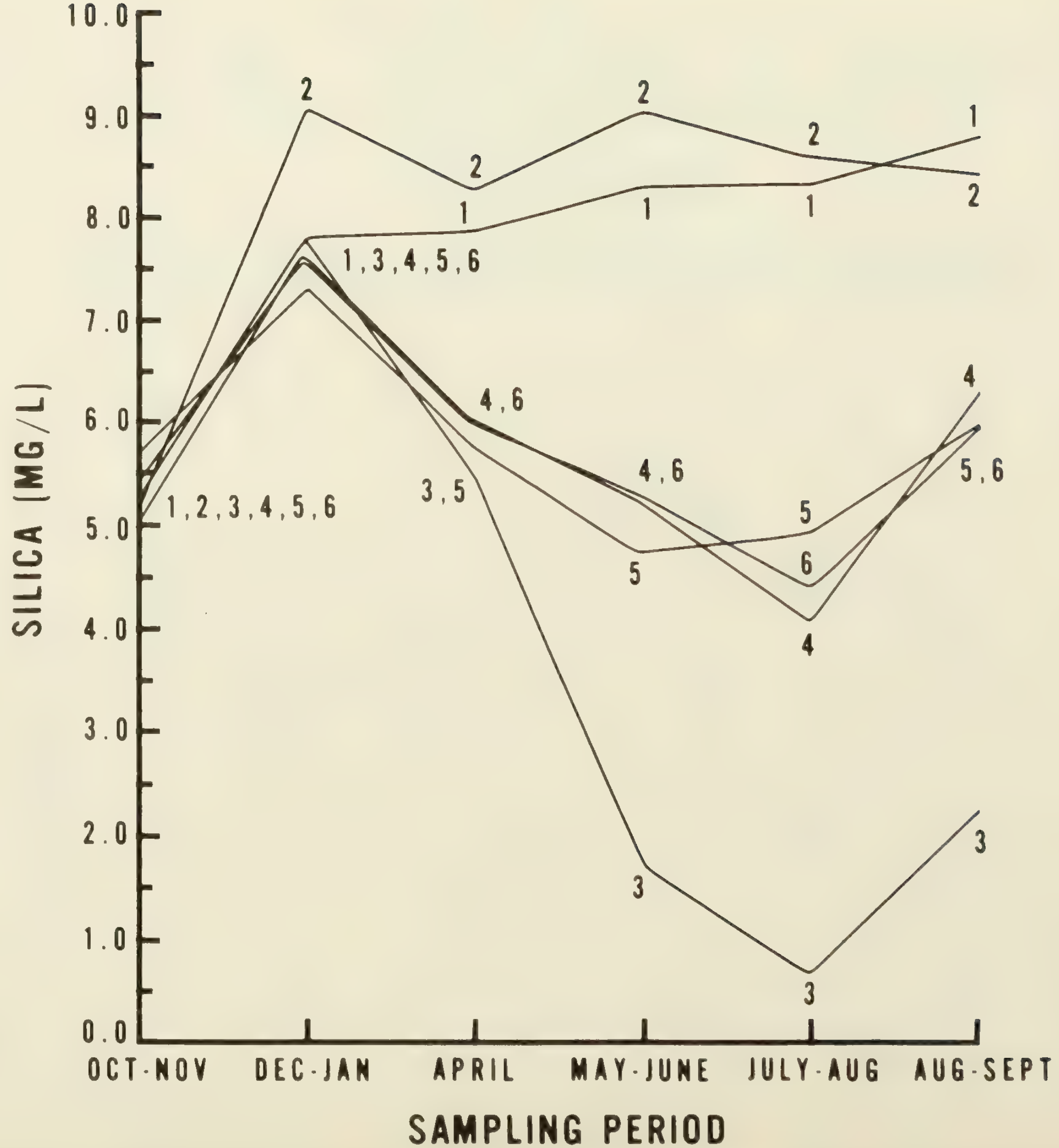

Figure 3-8-15. Mean silica concentrations for station groups during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Station Group 1 = Headwater; Group 2 = Tract; Group 3 = Yellow Creek; Group 4 = White River above confluence with Yellow Creek; Group 5 = White River at confluence with Yellow Creek; Group 6 = White River below confluence with Yellow Creek)

concentrations were generally highest at the tract stations and lowest at the headwaters. The quantity of organic carbon (both total and dissolved) was somewhat higher at the tract and Yellow Creek sites, most likely due to a greater inflow of allochthonous organic matter. Nitrate and Kjeldahl nitrogen were the most abundant forms of nitrogen found in the study area and the concentrations of orthophosphate, total phosphate, potassium and silica were all higher than those considered limiting for algal growth.

Final selection of chemical parameters for the monitoring phase must await accumulation and assessment of additional baseline data.

C. Sediment Studies

1. Objectives - The objective of this aspect of the Aquatic Baseline Studies is to determine certain characteristics of stream sediments to provide a measure of ambient (i.e., pre-development) conditions for comparison with conditions after tract development is initiated.

2. Methods - When possible, duplicate samples were collected at each sampling station. Chemical determinations included the following parameters: aluminum, arsenic, lead, mercury, Kjeldahl nitrogen, total phosphate, volatile solids, zinc, and the herbicides Tordon 22k and Silvex.

Analytical methods used were those outlined by EPA (1969, 1973), except that colorimetry was used for the determination of arsenic. Analytical methods and detection limits are outlined in Table 3-8-5. The indicated detection limits are considered to be nominal values; the actual minimum levels detected vary with sample size and type (size of clay fraction, type of clay material, etc.). Samples for pesticide analysis were collected in glass jars and were refrigerated for preservation. Samples for the other sediment analyses were placed in plastic bottles and frozen to preserve the sample.

In addition to these chemical analyses, stream substrates were visually categored (cobble, stone, gravel, sand, silt, clay, detritus, vegetation) during field surveys.

3. Data Summary and Discussion - A summary of site specific data concerning certain chemical characteristics of the sediments at the aquatic sampling sites are presented in Section 8.1C of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976). The following discussion presents analyses and interpretations of those site specific data.

Data on sediment chemical characteristics were collected primarily to define ambient conditions for comparison with levels during tract development. In general, the concentrations of sediment metals (aluminum, arsenic, lead,

mercury and zinc) and organic-related constituents (volatile solids, Kjeldahl nitrogen and total phosphate) tend to decrease from the headwaters to the White River. In addition to geographic location, sediment characteristics are also influenced to some extent by hydrological conditions. For some parameters (e.g., volatile solids, Kjeldahl nitrogen, mercury and arsenic), study maximum values (147,000 μg/g, 1,240 μg/kg, and 53 μg/g, respectively) were observed during relatively low flow periods. These trends were somewhat less evident in the White River, which was a relatively homogeneous environment relative to the other watershed segments studied.

The widespread use of pesticides has resulted in the ubiquitous nature of the residues of these materials. In aquatic ecosystems, pesticides commonly become associated with particulate organic and mineral components of the substrate. This accumulation often results in concentrations many times those observed in waters overlying these substrates (Feltz et. al., 1971; Federal Working Group on Pest Management, 1974).

In general, the concentrations of the herbicides Tordon 22K and Silvex in stream sediments near Tract C-a were below the measurable limits of the analytical method. Measurable amounts of Silvex were never observed. Tordon 22K was only found in measurable amounts during the fall (October) through spring (April) period in all four of the watershed segments considered (headwaters, tract, Yellow Creek and White River). These observations may be associated with the accumulation of organic matter and finer sediment mineral fractions during these relatively low flow periods.

D. Comprehensive Water Quality Studies

1. Objectives - The objectives of this aspect of the RBOSP Aquatic Baseline Studies is to conduct comprehensive water quality studies of the White River in order to establish a baseline for parameters not included under Section 8.1A (Physical Measurements) or 8.1B (Chemical Measurements).

2. Methods - Beginning in April 1975, duplicate water quality samples were obtained from the White River above (Station 25) and below (Station 34) Yellow Creek in accordance with the schedule outlined in Table 3-8-6. Laboratory analyses were performed in accordance with the methods referenced in Table 3-8-7. In addition, a spectrographic element scan was made of duplicate water samples on a quarterly basis. For each replicate sample, 2 liters of water were filtered and evaporated to dryness in the lab. The residue was dried at 105°C and the loss on ignition was determined at 800°C. The ash was then subjected to spectrographic analysis.

3. Data Summary and Discussion - Tables 3-8-8 through 3-8-13 include site specific data from the RBOSP water quality studies of the White River above (Station 25) and below (Station 34) the confluence with Yellow Creek. During the study period, the concentration of water quality parameters did not generally vary appreciably between sampling locations, but the concentrations of certain parameters did vary among sampling dates. The concentrations of fluoride varied only slightly between stations but varied considerably between the April 1975 sampling and the May - June 1975 sampling. The concentrations of carbon compounds, fluoride, mercury, organic nitrogen, and oils were highest during April 1975 and lowest during May - June 1975. Fecal coliform densities were also highest in April. The high concentrations of fecal coliform bacteria and of certain chemical parameters during April 1975 may be attributed to local thawing and runoff. The following discussion presents analyses and interpretations of these site specific data.

In evaluating the existing water quality of the White River near its confluence with Yellow Creek, the standards of both the Colorado Water Quality Control

Table 3-8-6. Water quality sampling frequency for RBOSP Aquatic Baseline Studies.

Parameter	Semi-Monthly	Quarterly
Arsenic (As), Diss	+	+
Barium (Ba), Diss	+	+
Boron (B), Diss	+	+
Cadmium (Cd), Diss	+	+
Carbon (C), Organic		+
Carbon (C), Organic Diss		+
Carbon (C), Organic Suspended		+
Chemical Oxygen Demand (O_2)		+
Chromium (Cr), Total Diss	+	+
Copper (Cu), Diss	+	+
Cyanide (Cn), Total	+	+
Fluoride (F), Diss	+	+
Iron (Fe), Total Diss	+	+
Lead (Pb), Diss	+	+
Lithium (Li), Diss	+	+
Manganese (Mn), Diss	+	+
Mercury (Hg), Diss	+	+
Nitrogen (N), Organic		+
Phosphorus (P), Total Diss	+	+
Phenolic compounds (Phenol)		+
Selenium (Se), Diss	+	+
Solvent extract (Oil)	+	+
Sulfate (S), Diss	+	+
Sulfide (S), Diss	+	+
Sulfur (S), Organic		+
Zinc (Zn), Diss	+	+
Fecal coliform bacteria		+
Pesticides		+
Radioactivity		+

Diss=Dissolved

Table 3-8-7. Water quality laboratory analysis methods for RBOSP Aquatic Baseline Studies.

Parameter	Method Reference
Arsenic (As), Diss	AA
Barium (Ba), Diss	AA
Boron (B), Diss	APHA - Carmine
Cadmium (Cd), Diss	AA
Carbon (C), Organic	Beckman Analyzer
Carbon (C), Organic Diss	Beckman Analyzer
Carbon (C), Organic Suspended	Beckman Analyzer
Chemical Oxygen Demand (O_2)	Dichromate Reflux
Chromium (Cr), Total Diss	AA
Copper (Cu), Diss	AA
Cyanide (Cn), Total	EPA (1971)
Fluoride (F), Diss	Orion Sp. Ion Electrode
Iron (Fe), Total Diss	AA
Lead (Pb), Diss	AA
Lithium (Li), Diss	AA
Manganese (Mn), Diss	AA
Mercury (Hg), Diss	Flameless AA
Nitrogen (N), Organic	Kieldahl minus Ammonia
Phosphorus (P), Total Diss	EPA (1971)
Phenolic compounds (Phenol	Distillation 4 - AAP
Selenium (Se), Diss	ASTM - Diaminobenzidine
Solvent extract (Al)	CCl_4 Extn. - IR
Sulfate (S), Diss	Gravimetric
Sulfide (S), Diss	APHA - Methylene Blue
Sulfur (S), Organic	Total (API) minus Total Inorganic
Zinc (Zn), Diss	AA
Fecal coliform	APHA
Lindane	GC
Malathion	GC
Parathion	GC
Toxaphene	GC
Radioactivity	Filtration, evaporation; low background, end window proportional counter

Diss=Dissolved
AA =Atomic Absorption
EPA =Environmental Protection Agency (1971)
APHA=American Public Health Association (1971)
GC =Gas chromatography

Table 3-8-8. Water quality data for RBOSP Aquatic Baseling Studies (data are expressed as mean values in mg/l unless otherwise noted.)

Parameter	April 1975		May-June 1975		August-September 1975		Overall Mean Values	
	Station 25	Station 34	Station 25	Station 34	Station 25	Station 34	Station 25	Station 34
Arsenic (As), Diss	<0.01	<0.01	<0.03	<0.03	<0.01	<0.01	<0.02	<0.02
Barium (Ba), Diss	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Boron (B), Diss	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cadmium (Cd), Diss	<0.01	<0.01	--	--	<0.01	<0.01	<0.01	<0.01
Carbon (C), Organic	14	12	--	--	<1	<1	<8	<7
Carbon (C), Organic Diss	12	11	--	--	2	<1	7	<6
Carbon (C), Organic Suspended	3	2	--	--	<1	<1	<2	<2
Chemical Oxygen Demand (O_2)	23	17	--	--	10	10	17	14
Chromium (Cr), Total Diss	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Copper (Cu), Diss	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Cyanide (Cn), Total	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Fluoride (F), Diss	0.60	0.70	0.07	0.06	<0.40	0.44	0.357	0.400
Iron (Fe), Total Diss	0.02	0.02	0.05	0.05	0.04	<0.02	0.04	0.03
Lead (Pb), Diss	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lithium (Li), Diss	0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Manganese (Mn), Diss	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mercury (Hg), Diss (ug/l)	3.5	0.3	0.7	0.7	0.3	<0.3	1.5	<0.4
Nitrogen (N), Organic	0.94	0.65	--	--	0.31	0.30	0.63	<0.48
Phosphorus (P), Total Diss	0.04	<0.03	0.02	0.03	0.02	0.02	0.03	0.03
Phenolic compounds (Phenol)	0.01	0.01	--	--	0.02	0.02	0.02	0.02
Selenium (Se), Diss	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Solvent extract (Oil)	0.130	0.150	<0.160	<0.022	<0.003	<0.003	<0.050	<0.058
Sulfate (S), Diss	55	51	16	16	51	58	41	42
Sulfide (S), Diss	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sulfur (S), Organic	<1	<2	--	--	5	5	<3	<4
Zinc (Zn), Diss	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Diss=Dissolved

Table 3-8-9. Summary of fecal coliform analysis from water quality studies, RBOSP Aquatic Baseline Studies, April and August - September 1975. (Results are expressed as means of number of colonies/100 ml.)

Station-Replicate	Colonies/100 ml
April 1975	
25	65
34	50
August - September 1975	
25	13
34	21

Table 3-8-10. Summary of radiological analyses for White River water quality studies, RBOSP Aquatic Baseline Studies. (Data are expressed in pCi/l.)

	Station Replicate			
	25		34	
	A	B	A	B
April 1975				
Gross Alpha (α)	1.2 ± 0.8	1.2 ± 0.8	1.3 ± 0.8	0.83±0.65
Gross (β) Beta	10.1 ± 1.6	9.4 ± 1.5	9.4 ± 1.5	8.0 ±1.4
August - September 1975				
Gross Alpha (α)	<0.56	<0.64	<0.52	<0.54
Gross (β) Beta	3.4 ± 0.8	2.6 ± 0.8	3.6 ± 0.9	3.6 ± 0.9

Table 3-8-11. Means of water quality data from spectrographic element scan for RBOSP Aquatic Baseline Studies, April 1975 - August - September 1975. (Data are means of two samples expressed in mg/l and are based upon dissolved solids.)

Parameter	April Station 25	April Station 34	August - September Station 25	August - September Station 34
Aluminum (Al)	0.01	0.02	0.008	<0.002
Antimony (Sb)	ND	ND	ND	ND
Arsenic (As)	ND	ND	ND	ND
Barium (Ba)	0.017	0.017	0.10	0.10
Beryllium (Be)	ND	ND	ND	ND
Bismuth (Bi)	ND	ND	ND	ND
Boron (B)	0.02	0.02	0.005	0.003
Cadmium (Cd)	ND	ND	ND	ND
Calcium (Ca)	54.3	53.5	175	157
Chromium (Cr)	ND	ND	<0.002	<0.002
Cobalt (Co)	ND	ND	ND	ND
Copper (Cu)	0.003	0.003	0.009	0.009
Germanium (Ge)	ND	ND	ND	ND
Iron (Fe)	0.011	0.013	0.006	0.017
Lead (Pb)	ND	ND	ND	ND
Magnesium (Mg)	22.8	22.7	43	44
Manganese (Mn)	ND	ND	0.008	0.009
Molybdenum (Mo)	ND	ND	ND	ND
Nickel (Ni)	ND	ND	0.007	0.007
Potassium (K)	6.3	6.4	0.96	1.65
Silica (Si)	0.07	0.09	0.66	0.13
Silver (Ag)	ND	ND	<0.004	<0.002
Sodium (Na)	189	186	18	40
Strontium (Sr)	2.4	2.8	9.0	9.2
Tellurium (Te)	ND	ND	ND	ND
Tin (Sn)	ND	ND	ND	ND
Titanium (Ti)	ND	ND	0.005[1]	<0.002
Vanadium (V)	ND	ND	ND	ND
Tungsten (W)	ND	ND	ND	ND
Zirconium (Zr)	ND	ND	ND	ND

ND = Not Detected
[1]The result for this analysis may represent lab error.

Table 3-8-12. Results of pesticide analyses for RBOSP Aquatic Baseline Studies, April 1975. (Data are expressed in mg/l and are the means of two samples).[1]

Parameter	Station	
	25	34
Lindane	<0.0001	<0.0001
Malathion	<0.0005	<0.0005
Parathion	<0.0001	<0.0001
Toxaphene	<0.002	<0.002

[1]All results were less than detection limits.

Table 3-8-13. Results of pesticide analyses for RBOSP Aquatic Baseline Studies, August - September 1975. (Data are expressed in mg/l and are the means of two samples.)[1]

Parameter	Station	
	25	34
Lindane	<0.0001	<0.0001
Malathion	<0.0005	<0.0005
Parathion	<0.0001	<0.0001
Toxaphene	<0.002	<0.002

[1]All results were less than detection limits.

Commission (1974) and the U. S. Public Health Service (1962) were used. Table 3-8-14 lists both the maximum allowable and recommended limiting concentrations of chemical parameters for public drinking water. The recommended limiting concentrations are those which should not be exceeded when more suitable supplies can be made available. These recommended limiting concentrations are based primarily upon taste and odor considerations, whereas, the maximum allowable limits are based on the toxicity of the constituents to humans.

During the period of study, none of the levels observed exceeded the maximum allowable limits or recommended limiting concentrations of the U. S. Public Health Service (1962). Levels of gross beta radioactivity in samples from the White River were well below the maximum allowable U. S. Public Health Service limit of 1,000 pCi/l.

Fecal coliform counts were significantly lower than the standards of the Colorado Water Control Commission (1974) for Class B_2 waters. (Bacteriological concentrations for Class B_2 waters do not exceed a geometric mean of 10,000 total coliform groups or 1,000 fecal coliform groups per 100 ml based on a minimum of not less than five samples obtained during separate 24 hr periods for any 30 day period, nor do 10% of the fecal coliform samples exceed 2,000 per 100 ml during any 30 day period.)

Table 3-8-14. Maximum allowable and recommended limiting concentrations for chemical parameters in drinking water.

	Recommended Concentrations (mg/l)	Maximum Allowable Concentrations (mg/l)
Arsenic (As), Diss	0.01	0.05
Barium (Ba), Diss		1.0
Cadmium (Cd), Diss		0.01
Copper (Cu), Diss	1	
Cyanide (Cn), Total	0.01	0.2
Fluoride (F), Diss[1]	0.8-1.7	1.7
Iron (Fe), Total Diss	0.3	
Lead (Pb), Diss		0.05
Manganese (Mn), Diss	0.05	
Selenium (Se), Diss		0.01
Sulfate (S), Diss	250	
Zinc (Zn), Diss	5	

Diss = Dissolved

Source: United States Public Health Service (1962)

[1]Limits are based upon annual average of maximum daily air temperatures.

E. Springs and Seepages

1. Objectives - The objective of this aspect of the RBOSP Aquatic Baseline Studies is to identify and record the locations of springs and seeps on Tract C-a as they are encountered during routine aquatic sampling.

2. Methods - During routine aquatic sampling, the locations of springs and seeps were noted and recorded as they were encountered.

3. Data Summary and Discussion - The locations of springs and seeps on Tract C-a are identified in Chapter 4 of Section 3.

8.2 BIOTIC

A. Phytoplankton

1. Objectives - The objectives of phytoplankton studies are to determine the species composition and abundance of the phytoplankton as an aid in characterizing the aquatic habitats on and near Tract C-a.

2. Methods - At each station, duplicate samples were collected with pump-type samplers concurrently with water chemistry samples. Phytoplankton samples were transferred to opaque bottles containing premeasured quantities of Lugol's preservative. These samples were then stored in the dark until processing. Laboratory methods are described in Section 8.2A of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976).

3. Data Summary and Discussion - The term phytoplankton refers to the plant portion of the community of free-floating aquatic microorganisms. Site specific data concerning phytoplankton abundance and composition for the 1-yr period are presented in Section 8.2A of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976). The following discussion presents analyses and interpretations of those site specific data.

The species composition and abundance of phytoplankton of the sampling stations in the headwater and tract regions were generally similar, except at Station 17 during August - September 1975 when a great abundance of green and blue-green algae was observed. In both of these regions, the dominant algal group was Chrysophyta, particularly the diatoms. The diatom *Achnanthes minutissima* appeared to be the most ubiquitous of all the species in the two regions. It was reported by Lowe (1974) to be periphytic, alkaliphilous (best development occurring at pH greater than 7), tolerant to small amounts of salt, and common in springs and streams. Lowe (1974) also noted that *Achnanthes minutissima* is very ubiquitous and is a good indicator of high oxygen concentrations in alkaline waters. The abundance of this taxon in the plankton can undoubtedly be attributed to its importance in the periphyton community (see Section 8.2.C).

In the headwater and tract regions, phytoplankton abundance was highest during the spring and late summer and the greatest abundance was recorded in the tract region (Figures 3-8-16 and 3-8-17). The phytoplankton of the headwater and tract regions was generally dominated by periphytic forms, although species that are considered euplanktonic (Lowe, 1974; Prescott, 1962), such as Nitzschia holsatica, Synedra ulna, Chroococcus dispersus, and Chrysidiastrum ocellatum, were common. The composition of the phytoplankton generally reflected the alkaline conditions of the streams. Phytoplankton abundance was generally low in the streams and ponds of the regions, thus lending support to the contention of Prescott (1968) that there is little phytoplankton in such spring-fed streams. However, the two periods of increased phytoplankton abundance and the differing composition during the two periods suggest that the spring maximum was due to an increase in recruitment of periphyton species, whereas the late summer increase (primarily at Station 17) of green and blue-green species was caused by the increased development of planktonic taxa.

The composition and abundance of the dominant phytoplankton taxa in lower Yellow Creek was generally different from that of the headwater and tract regions (Figure 3-8-18). In Yellow Creek, there was a major difference between the composition and abundance of phytoplankton at Station 19 (a pond area) and that of other stations. Generally, phytoplankton abundance was considerably greater at Stations 20 - 22 than at Station 19. These differences in phytoplankton composition and abundance are likely related to differences in tolerances to such chemical factors as sulfate and hardness, both of which were highest at Station 19, while dissolved solids, sodium and chloride concentrations were generally higher at other Yellow Creek stations.

The different physical configuration of Station 19 (a pond) also undoubtedly contributed to the differences observed. The species which was generally most ubiquitous and numerous at Stations 20 - 22 was Cyclotella meneghiniana. This species is characterized by Lowe (1974) as being periphytic, tychoplanktonic, or euplanktonic, has an optimum pH range of 8.0 to 8.5 and is stimulated by small amounts of salt. Another species commonly found at Stations 20 - 22 was Cymbella affinis. Lowe (1974) reported that this species has an optimum pH range of 7.8 to 8.5 and tolerates small amounts of salt (less than 500 mg/l).

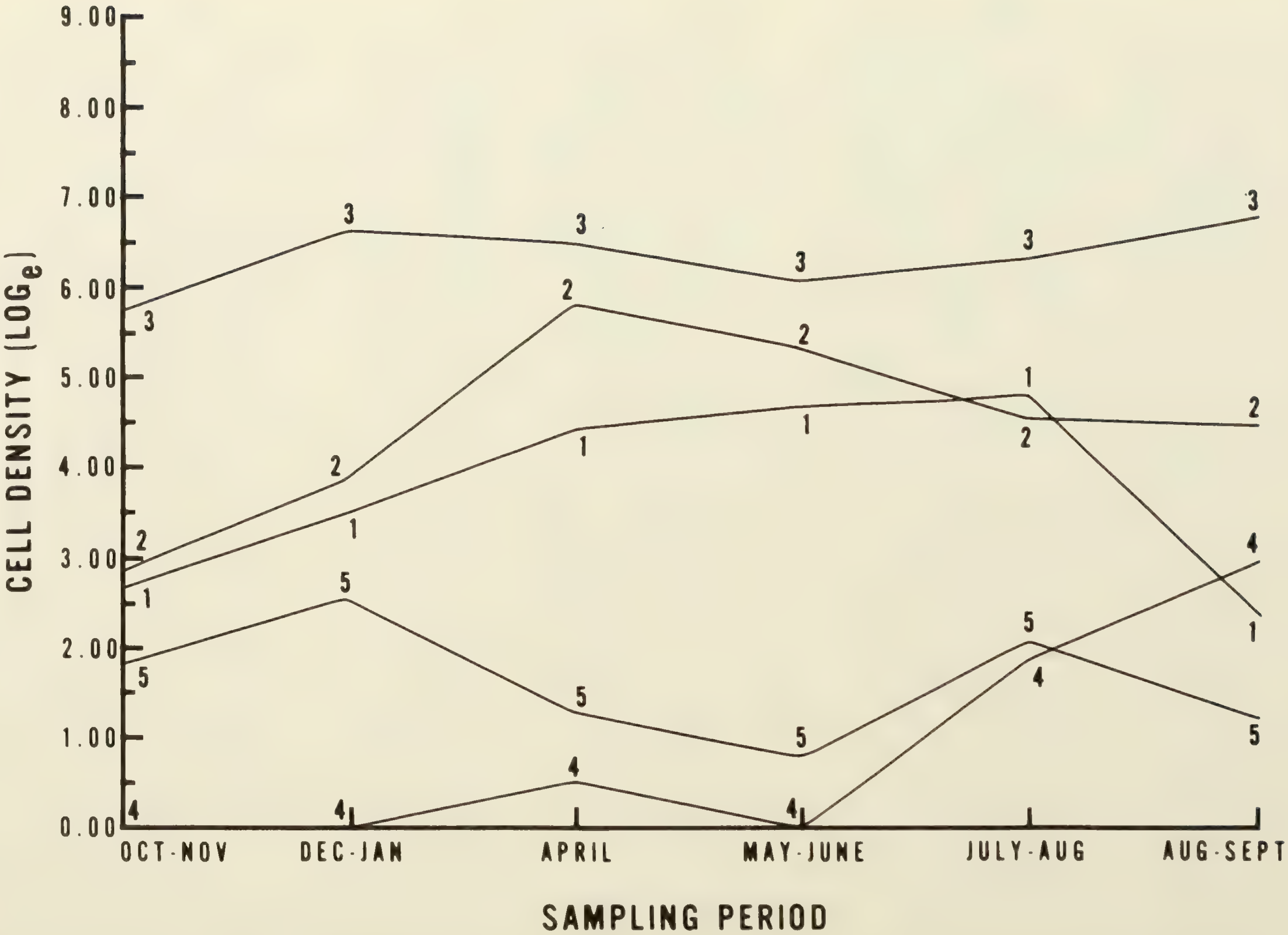

Figure 3-8-16. Log mean densities of the major algal groups in the phytoplankton at the Headwater stations during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Cyanophyta = 1; Chlorophyta = 2; Chrysophyta = 3; Euglenophyta = 4; Pyrrhophyta = 5; Cryptophyta = 6)

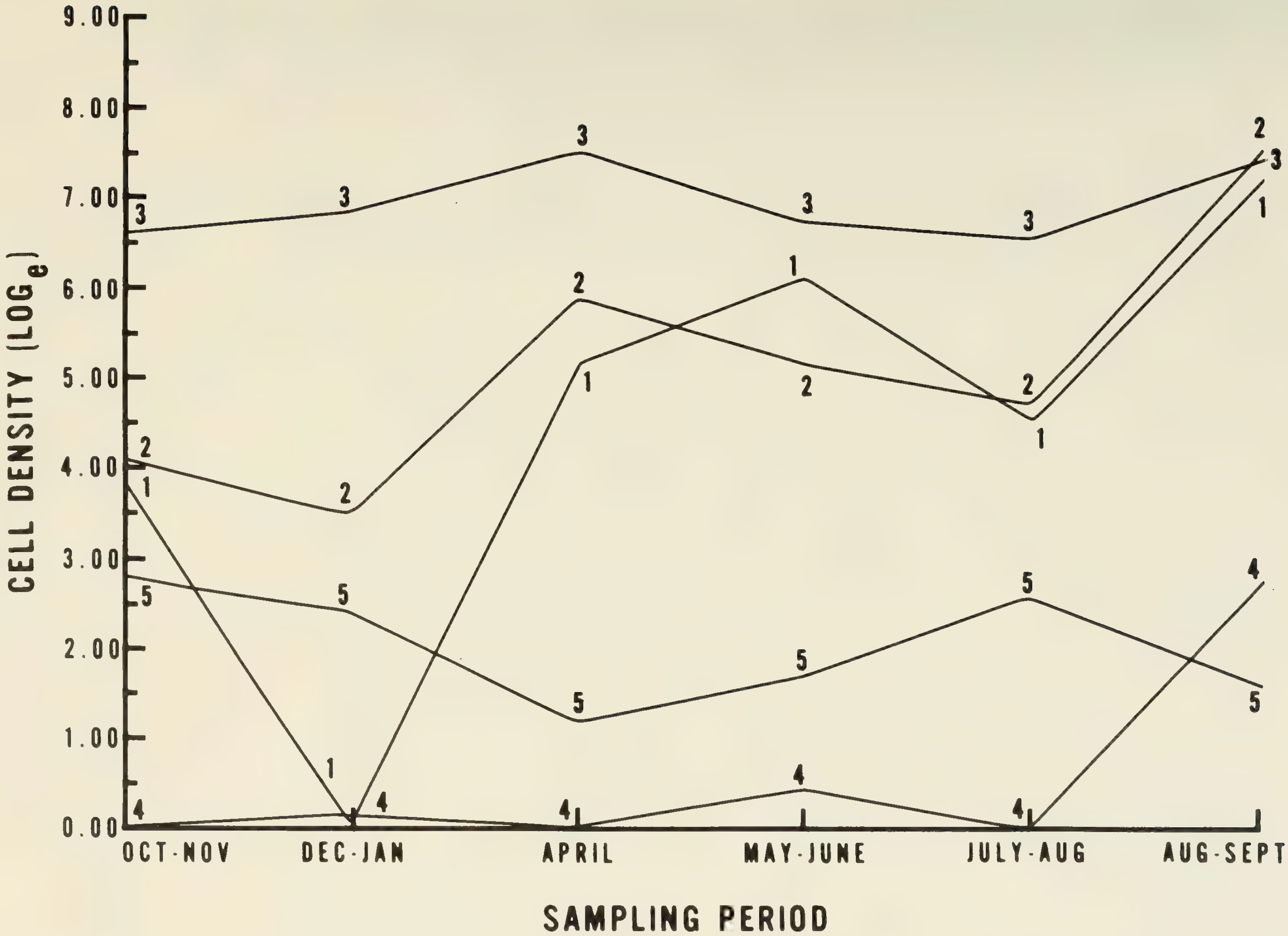

Figure 3-8-17. Log mean densities of the major algal groups in the phytoplankton at the Tract stations during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Cyanophyta = 1; Chlorophyta = 2; Chrysophyta = 3; Euglenophyta = 4; Pyrrhophyta = 5; Cryptophyta = 6)

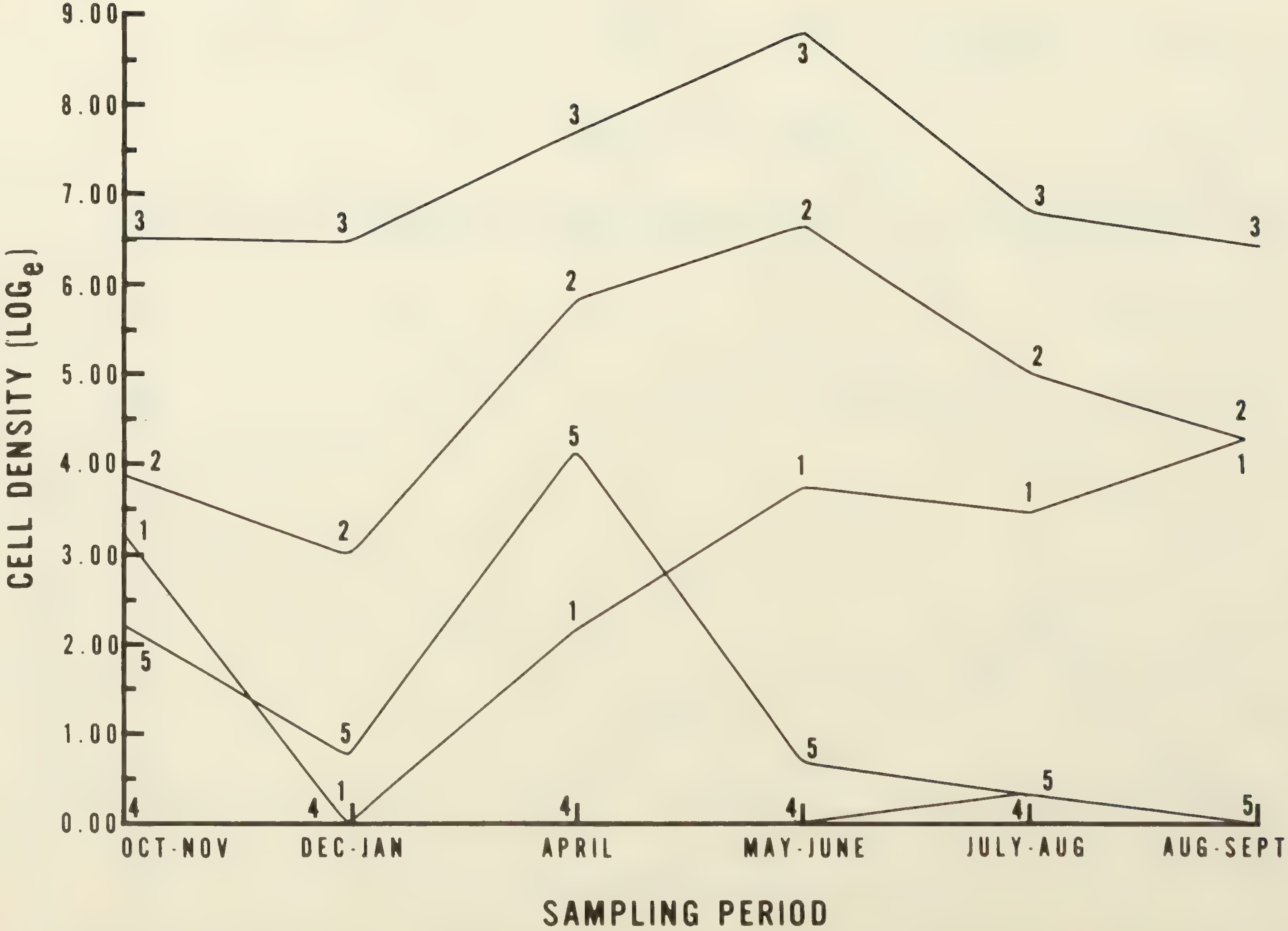

Figure 3-8-18. Log mean densities of the major algal groups in the phytoplankton at the Yellow Creek stations during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Cyanophyta = 1; Chlorophyta = 2; Chrysophyta = 3; Euglenophyta = 4; Pyrrhophyta = 5; Cryptophyta = 6)

The composition and abundance of the dominant phytoplankton in the White River was also generally different from the phytoplankton in either Yellow Creek or in the headwater and tract areas. In the White River, the number of taxa observed in the areas above and below the confluence with Yellow Creek were similar, but the increased development of Cyanophyta (blue-greens) occurred somewhat later at and below the area of the confluence (Figure 3-8-19, 3-8-20, and 3-8-21). During the April and May - June 1975 sampling periods, the composition of the dominant phytoplankton taxa differed between the confluence area and the two other areas (above and below the confluence).

In the White River, the phytoplankton contained a mixture of algae derived from both periphytic and planktonic habitats. Generally, the abundance of phytoplankton was greatest during the spring and was not as great as that in Yellow Creek. Phytoplankton abundance in the White River was expected to be lower because of the paucity of slack-water areas.

The algal taxa in the phytoplankton of the streams considered in the RBOSP Aquatic Baseline Studies were apparently derived from both periphytic and planktonic habitats. The species compositon of the phytoplankton was similar among the various sampling areas and there were distinct differences in the dominant taxa among the various areas. These differences undoubtedly reflect differences in physical and chemical characteristics of the sampling areas as well as differences in the potential sources of phytoplankton recruitment (i.e., benthic algae, pools, etc.). In general, in all waters of the study the phytoplankton is a secondary source of autochthonous primary production and phytoplankton abundance was low.

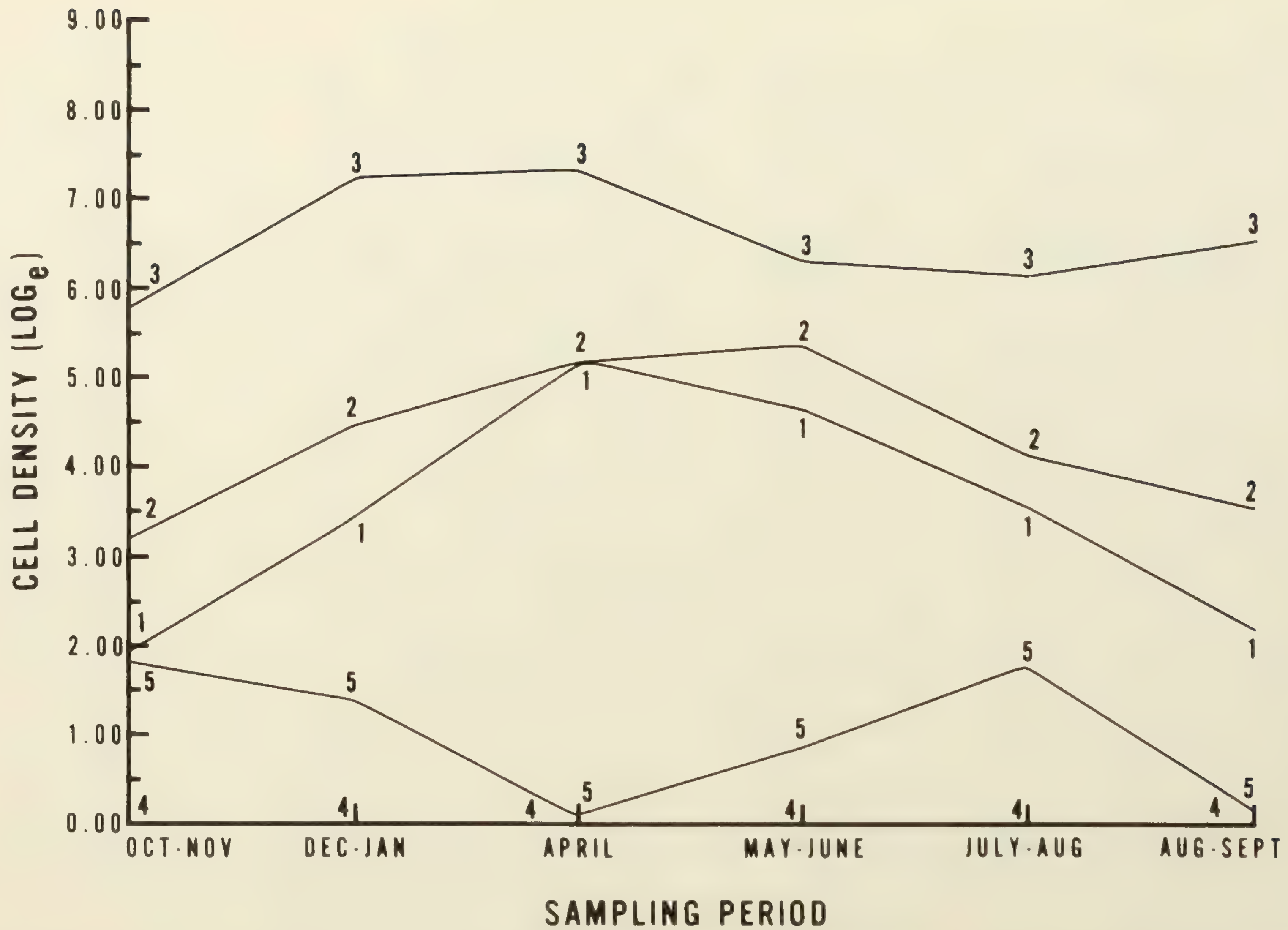

Figure 3-8-19. Log mean densities of the major algal groups in the phytoplankton of the White River stations above confluence with Yellow Creek during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Cyanophyta = 1; Chlorophyta = 2; Chrysophyta = 3; Euglenophyta = 4; Pyrrhophyta = 5; Cryptophyta = 6)

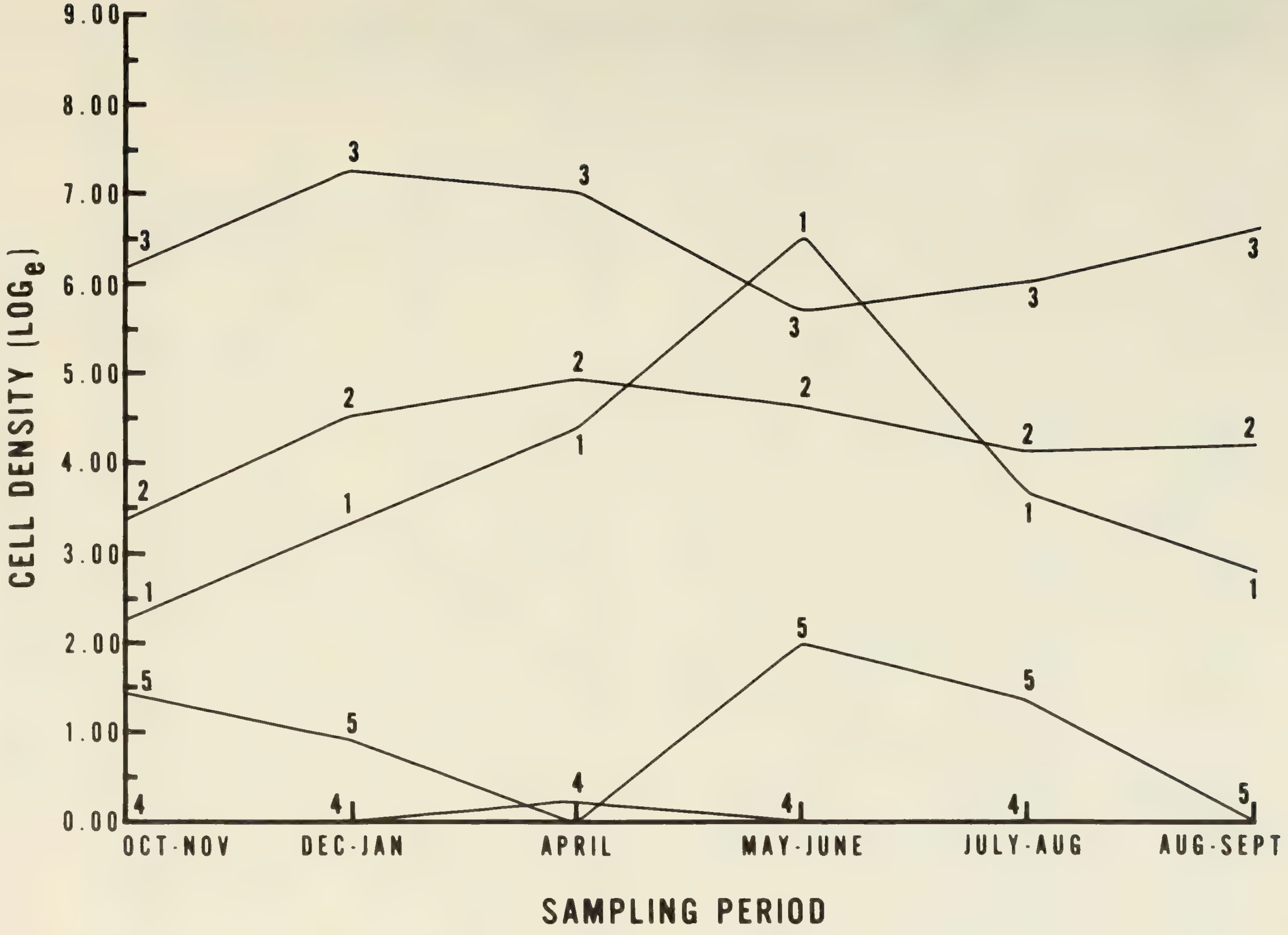

Figure 3-8-20. Log mean densities of the major algal groups in the phytoplankton of the White River stations at confluence with Yellow Creek during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Cyanophyta = 1; Chlorophyta = 2; Chrysophyta = 3; Euglenophyta = 4; Pyrrhophyta = 5; Cryptophyta = 6)

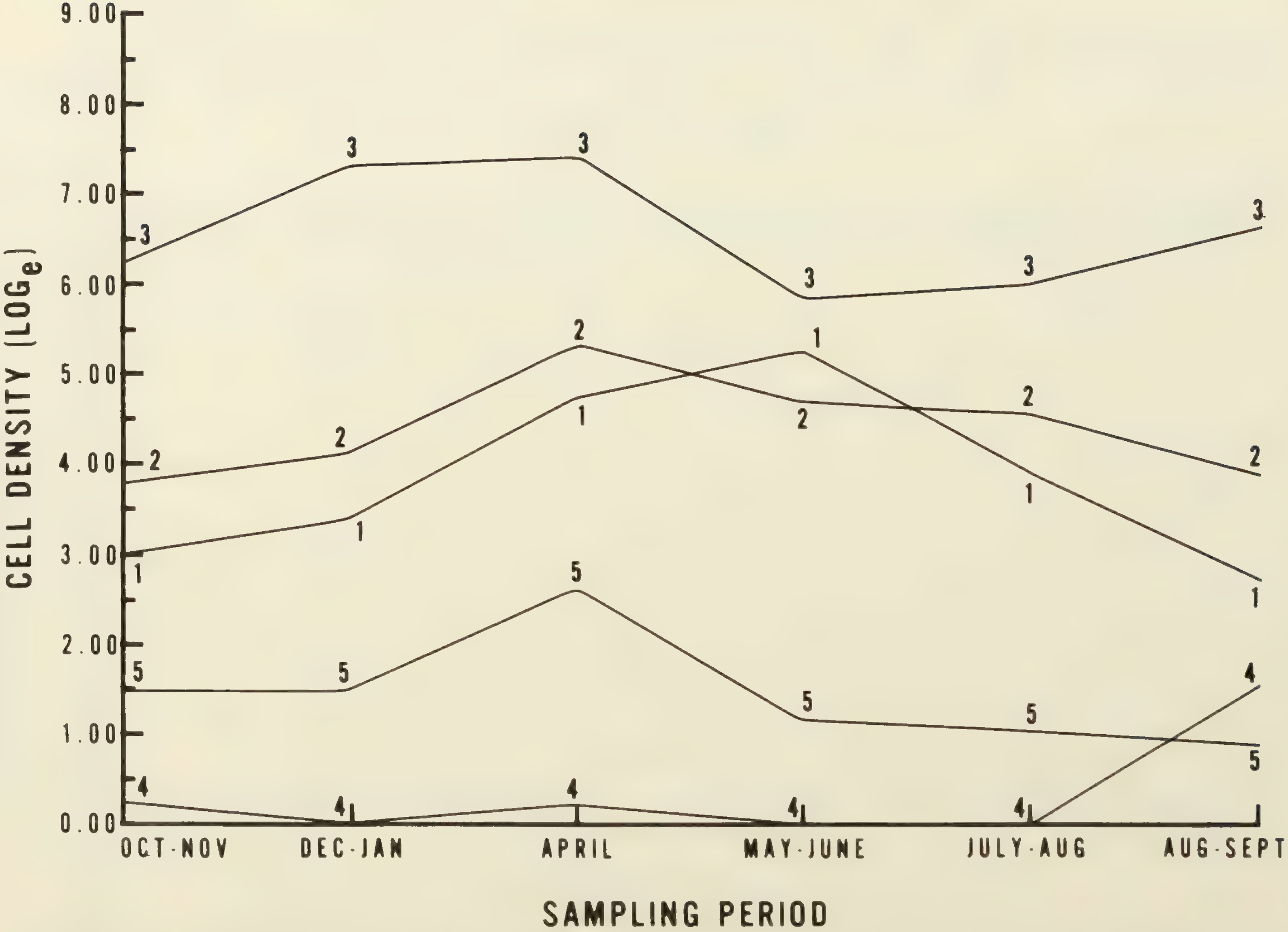

Figure 3-8-21. Log mean densities of the major algal groups in the phytoplankton at the White River stations below confluence with Yellow Creek during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Cyanophyta = 1; Chlorophyta = 2; Chrysophyta = 3; Euglenophyta = 4; Pyrrhophyta = 5; Cryptophyta = 6)

B. Zooplankton

1. Objectives - The objectives of this aspect of the RBOSP Aquatic Baseline Studies are to collect and identify the plankton species present in the streams and to describe the plankton community at each station.

2. Methods - Between October - November 1974 and April 1975 a portable pump was used to collect zooplankton samples of at least 85, and usually 100, liters at all stations, except Stations 23 - 35 (White River). The samples were pumped into a carboy of known volume and filtered through a conical plankton net of No. 25 Nitex (64 μ mesh). At Stations 23 - 35, samples were collected with a 30-cm-diameter conical plankton net (No. 25) for a period of time which allowed at least 100 liters of water to be sampled. This volume was measured by a calibrated General Oceanics digital flowmeter centered at the mouth of the net. During and after the May - June 1975 sampling, all zooplankton samples were collected with a portable pump as described above.

The concentrated samples (100 to 200 ml) were preserved with 3 - 5% neutralized formalin. Time of collection and other pertinent information were recorded in the field notes. Samples of live material were periodically analyzed for identification of certain microplankters, particularly ciliates, which do not preserve well. Laboratory methods are described in Section 8.2.B of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976).

3. Data Summary and Discussion - The term zooplankton refers to the animal portion of the community of free-floating aquatic microorganisms. Site specific data concerning composition and abundance of zooplankton for the 1-yr period are presented in Section 8.2B of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976). The following discussion presents analyses and interpretations of those data.

Two habitat types were sampled at the headwaters and on and near the tract. The habitat sampled at Stations 1 - 4, 7 - 9 and 13 is that of a cold spring

brook which has very near constant temperatures throughout the year. The bottom substrates consist of gravel, sand and shale chunks often covered by periphyton. Macrophytes were absent or rare, possibly explaining the low numbers of littoral Rotifera and Cladocera. The high densities of Centropyxis spp. at Stations 7, 8, 9 and 13 can be related to spring run-off due to snow-melt, as these stations were very turbid during sampling. The dominant Crustacea observed included the cyclopoid Eucyclops agilis and the harpacticoid Bryocamptus hiemalis. Eucyclops agilis is a cosmopolitan species common in a wide variety of habitats, including cold springs (Rylov, 1948). No information is available as to the habitat requirements of Bryocamptus hiemalis; however, a form of this species, Bryocamptus hiemalis brevifurca, has been collected from a lake in New York and several habitats in North Carolina, including a brook, a marsh and a small spring filled with leaves and debris (Coker, 1934). Information describing the tolerances to such factors as salinity and alkalinity is not available for this particular species; however, Remane and Schlieper (1971) listed fresh-water Harpacticoida as often intolerant of saline waters. Temperature may possibly be more important in controlling the distribution of Bryocamptus hiemalis, since several specimens were collected at the lower Yellow Creek stations (20 - 22) in the winter sampling but none were observed in other months. Bryocamptus hiemalis, including ovigerous females, was abundant throughout the year at the spring-brook stations.

Stations 6, 12, 15 and 17 - 19, which were dry much of the year but flowed at least once, were characterized by a fauna similar to that at stations on the spring-brooks from which they received their flow.

Stations 5 and 14 were representative of a littoral pond habitat. Station 5 was located at the outlet of a marshy, pond-like seepage area. This seepage area (the source of flow at Station 5) extended as far as 800 meters (0.5 miles) above the station. The whole area was relatively flat and covered

by sedges, cress and other vegetation. As a result, the zooplankton at Station 5 was comparable to that at the lower Yellow Creek stations (19 - 22). Species composition and factors controlling the spatial and temporal distribution of several of the organisms at Station 5 will therefore be included in the discussion of Stations 19 - 22.

Macrocyclops albidus, a cosmopolitan cyclopoid, occurred only at Station 5. This species inhabits the same wide variety of habitats as does Eucyclops agilis. Rylov (1948) described Macrocyclops albidus as common in habitats similar to the marsh above Station 5, as tolerant of strongly alkaline waters, and as markedly euryhaline. Because only six individuals were found and then only during July - August 1975, its rarity may explain its absence from samples taken at the lower stations.

Station 14 is a pond in Corral Gulch which is utilized as a source of water for settling dust on the adjoining dirt road. During the summer, the pond developed thick mats of Zannichellia palustris which covered the entire pond by August 1975. These mats had also been present in October - November of the previous year. A seepage approximately 400 m (0.25 mi) upstream of the pond provided a constant flow through the pond. The dominant taxa consisted of littoral forms of rotifers and crustaceans. The dominance of Ceriodaphnia quadrangula at Station 14, as compared with its relative subordinance to Alona and Pleuroxus at similar habitats at Station 5 and in the lower section of Yellow Creek, may be related to the lower specific conductivities at Station 14, but more likely to the presence of Zannichellia palustris or horned pond weed at Station 14. Quade (1969), during a study of the affinities of Cladocera to aquatic plants, observed that the highest abundance of Ceriodaphnia was associated with Najas, a fine-leaved submersed pond weed similar in structure to Zannichellia (Fassett, 1957). The high diversity and densities of littoral rotifers, such as bdelloids, Monostyla, Lepadella, Euchlanis and other monogononts, are probably related to the rich growth of the macrophyte as the abundances of littoral rotifers are governed by the amount of available substrate (Pennak, 1953).

Seasonal densities of the major zooplankton groups at the headwaters and tract stations are shown in Figures 3-8-22 and 3-8-23.

The lower section of Yellow Creek can be described as a slightly brackish (Pennak, 1974) littoral habitat; alkalinities and conductivities are considerably higher than at the stations near the tract. The lower stations (20 - 22) were very similar to each other (all are within 400 m (0.25 mi) of each other), and zooplankton samples were taken from essentially the same water mass. Samples at these stations were generally collected on the same day and usually within a short time of one another. Differences in species composition and densities among these stations may be related to such changing physical variables as water temperature, DO and conductivity as these characteristics were observed to vary diurnally.

The accidental presence of benthic Rhizopoda species in the plankton is well illustrated at the lower stations in April. After samples were taken at Station 22, a flock of sheep crossed the creek just upstream of Station 20, significantly increasing the turbidity in the stream. Samples taken shortly thereafter at Stations 21 and 20 showed considerably higher densities of rhizopods than were observed at Station 22.

A similar occurrence can explain the relatively high density of Centropyxis spp. at Station 20 in July 1975. The pump used in collection of zooplankton samples developed mechanical difficulty, necessitating that a dipping method be used to collect the sample volume. Dipping apparently disturbed the substrate sufficiently to introduce a large number of Centropyxis spp. into the plankton, resulting in relatively high densities of Centropyxis spp. in the sample.

The great abundance of Chara kieneri at Station 19 and its absence from the lower stations, the wide diurnal variation of temperatures at the lower stations, the consistently cooler temperatures at Station 19, and the pond conditions at Station 19 were contributing factors to the differences in species composition and abundance between Station 19 and the lower stations. However,

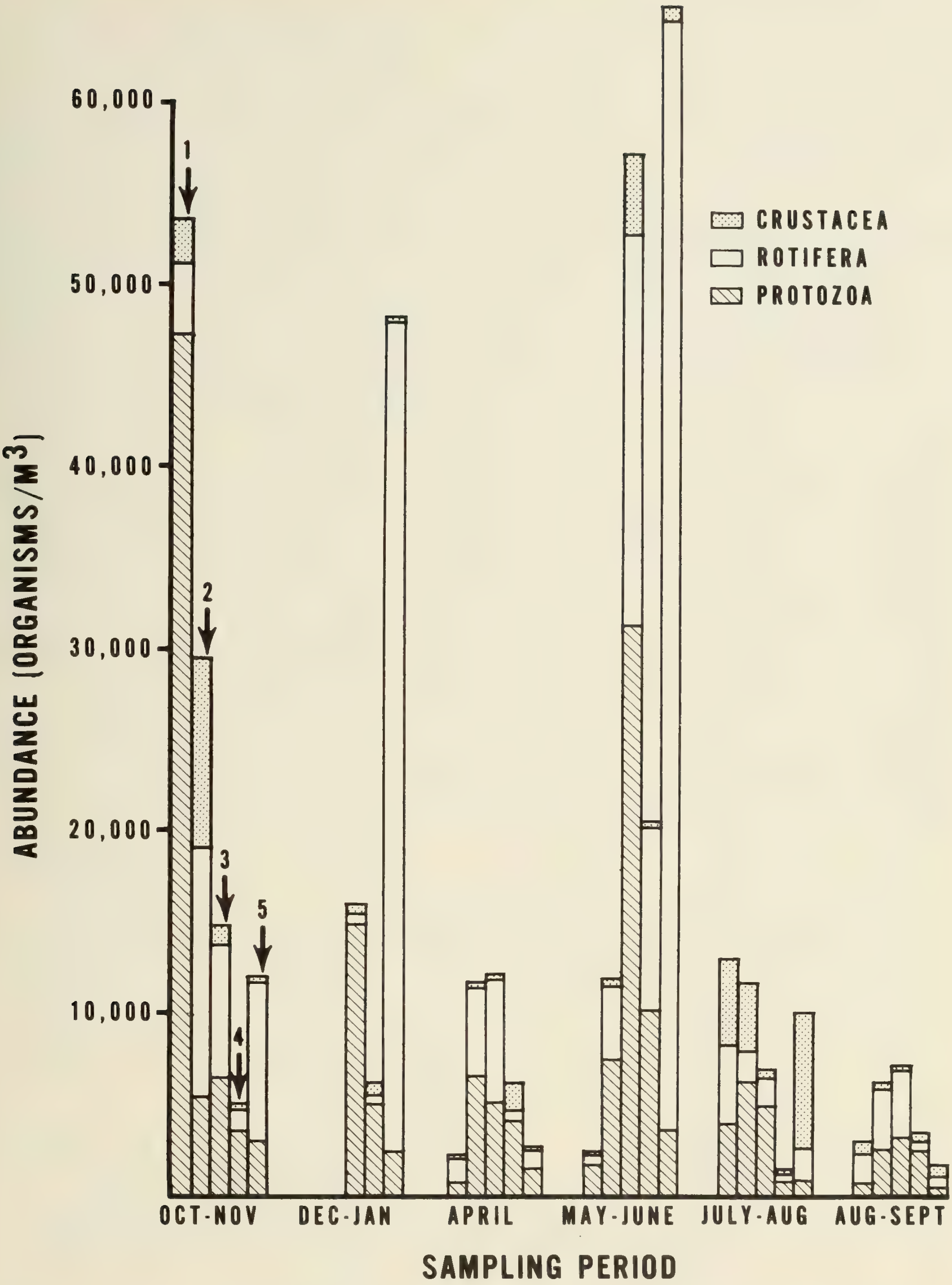

Figure 3-8-22. Zooplankton densities observed at the Headwater stations (1 - 5) during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (During December 1974 - January 1975 samples were collected at Stations 3- 5 only)

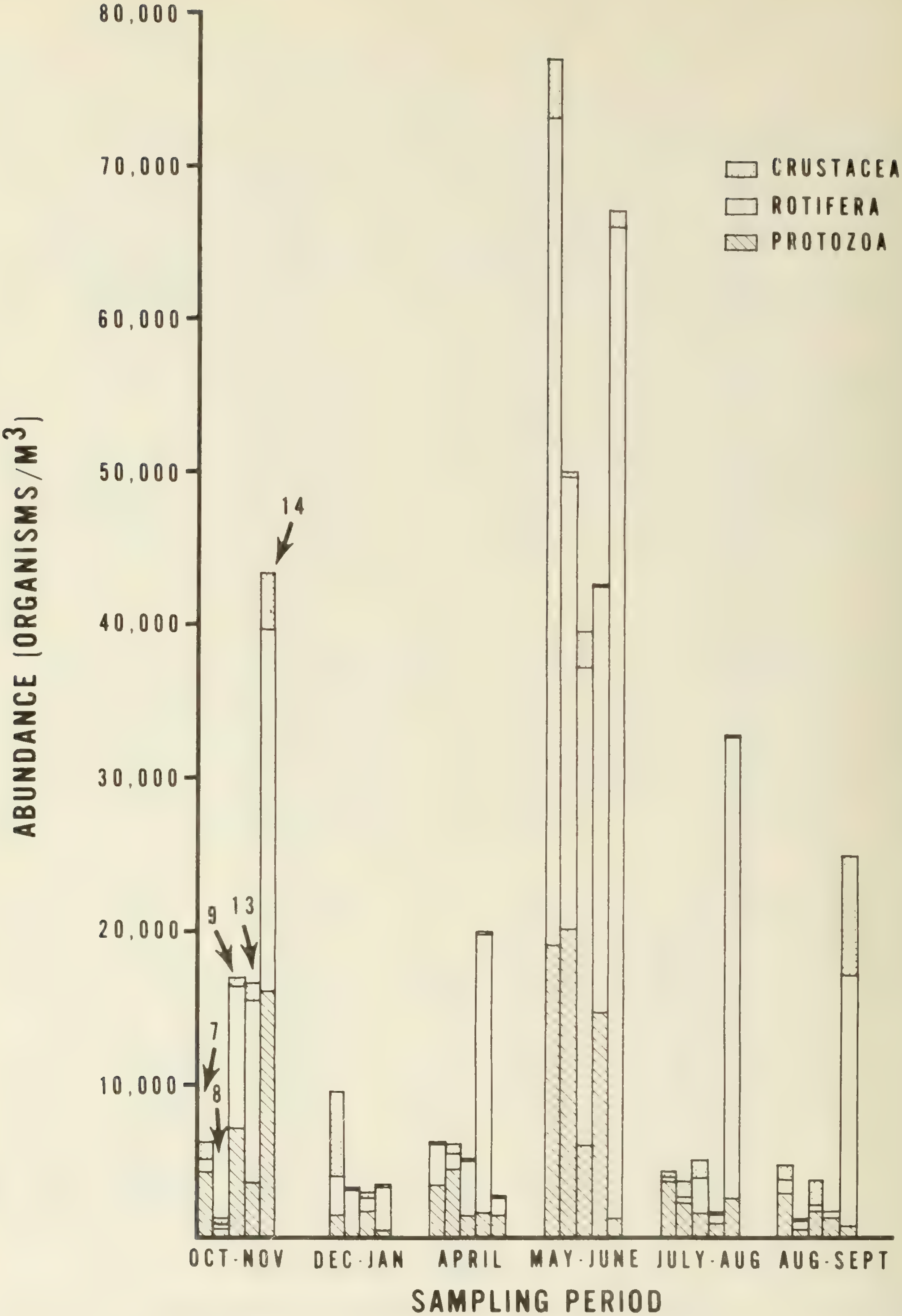

Figure 3-8-23. Zooplankton densities observed at the Tract stations (7, 8, 9, 13, 14) which were generally flowing during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (During December 1974 - January 1975, samples were taken at Stations 8, 9, 13, 14 only)

very high alkalinities and high conductivities were characteristic of both areas.

The rotifer fauna at Yellow Creek stations was identical to that which occurred throughout the study area. This faunal list consists almost entirely of cosmopolitan species characteristic of alkaline waters (Myers, 1931; Ahlstrom, 1932; Edmondson, 1936). The species present, e.g., Notholca acuminata, Notholca squamula and Colurella adriatica are also very tolerant of brackish water and even sea water (Remane and Schlieper, 1971).

Temperature is probably the most important factor controlling the abundance of Notholca species in the four Yellow Creek stations. Notholca has been described as a cold stenotherm intolerant of temperatures of 25^{0}C or higher (Ruttner-Kolisko, 1974), although Carlin (1943) found that, in brackish water, it apparently occurs in summer at high temperatures. The pond at Station 19 showed little of the daily temperature fluctuation that was observed at the lower stations, and thus presented a more suitable habitat for the Notholca species. However, an increase in temperature from 14^{0}C to 22^{0}C (in June and July, respectively) apparently produced a great decrease in the Notholca populations at this station.

Several differences in the distribution of Crustacea occurred at the Yellow Creek stations. The abundance of Eucyclops agilis is not unexpected, as this cyclopoid is found in a wide variety of habitats. The presence of mature forms throughout the year, its adaptability to widely changing temperatures, and its euryhaline characteristics (Rylov, 1948) account for its abundance throughout the year in Yellow Creek. The appearance of Eucyclops speratus, Cyclops vernalis and Paracyclops fimbriatus poppei are perhaps adventitious, as the first two are likely intolerant of brackish waters and the third is usually not present in waters of high alkalinity (Rylov, 1948). However, Remane and Schlieper (1971) described Eucyclops speratus as tolerant of low salinities.

Although Cladocera, in general, are restricted to freshwater areas of less than 1% salinity, such species as Ceriodaphnia quadrangula, Chydorus sphaericus

and Simocephalus vetulus have been found to occur in salinities up to 4 - 5% (Remane and Schlieper, 1971). Alona rectangula, a species closely related to Alona circumfimbriata, has been found in salinities of 13.8% (Smirnov, 1971). In addition, one species of Pleuroxus, i.e., Pleuroxus trigonellus, occurs in salinities up to 2.1% (Smirnov, 1971).

The Cladocera observed are typically summer, littoral species, thus accounting for their abundance in August - September. The differences in relative abundance among the four Yellow Creek stations may be related to vegetation type and density. The higher relative abundance of Pleuroxus aduncus at lower Yellow Creek stations may be correlated to the abundance of filamentous algae in the stream in late summer (Smirnov, 1971). The dense mats of Chara at Station 19 may account for the high population density of Alona circumfimbriata, as affinities to Chara have been documented for Alona costata and Alona guttata (Quade, 1969), two species of similar size as Alona circumfimbriata.

Seasonal densites of the major zooplankton groups at the Yellow Creek stations are shown in Figure 3-8-24.

Most studies of the zooplankton of rivers have concluded that the fauna present is planktonic, and has been contributed by lakes, ponds and quiet areas along the drainage system. Such is not the case with the White River, as the majority of the organisms found are not planktonic but are benthic or littoral. As a result, the plankton densities observed in the White River (Figure 3-8-25) are generally lower than those reported in other studies of larger, slower-moving streams (Kofoid, 1908; Eddy, 1932).

The dominance of the Rhizopoda, i.e., Centropyxis spp., in the White River samples is of interest. One study (Reinhard, 1931) showed these taxa to be almost non-existent in river plankton. The Rhizopoda are considered as benthic organisms and their presence in river plankton is largely a result of disturbances by the current (Kofoid, 1908; Pennak, 1943). This would explain the consistency of densities from October to April as flow conditions were somewhat uniform during this period. The low densities in June 1975, during the flood stage of the

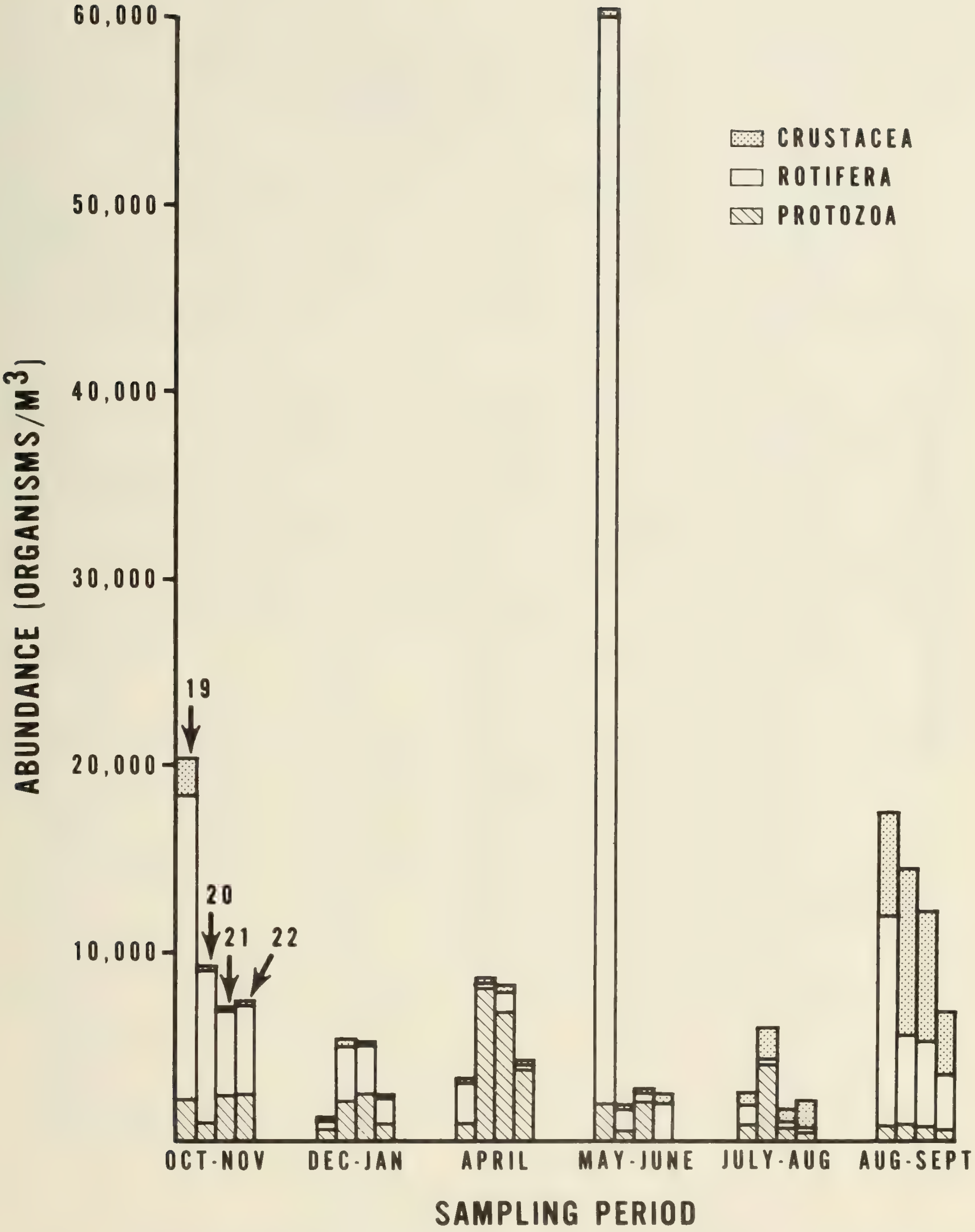

Figure 3-8-24. Zooplankton densities observed at the Yellow Creek stations (19 - 22) during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975.

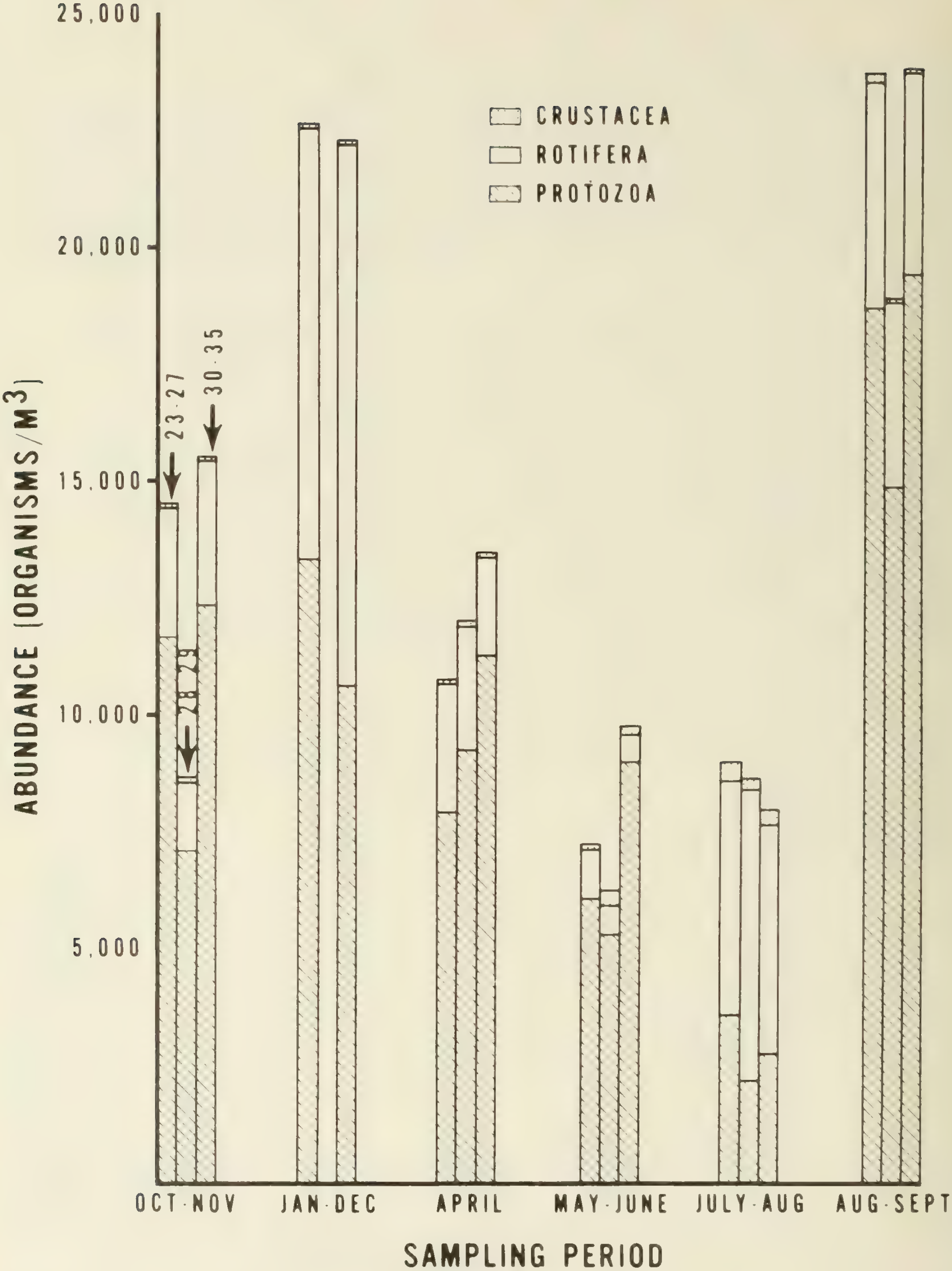

Figure 3-8-25. Zooplankton densities for station groups (23 -27; 28 - 29; 30 - 35) in the White River during RBOSP Aquatic Baseline Studies from October - November 1974 to August - September 1975. (Samples could not be collected at Stations 28 - 29 during December 1974 - January 1975)

river, suggested that although the bottom sediments were disturbed to a greater extent than normal, the larger number of rhizopods introduced into the water column was diluted or had already been flushed away.

Increased rhizopod densities in September are significant as this phenomena has been documented previously (Kofoid, 1908). Hutchinson (1967) and Hynes (1970) considered these marked increases of rhizopods in the plankton as a physiological adaptation to anaerobic conditions at the substrate interface.

The rotifer fauna differed considerably from what is normally found in rivers. Planktonic forms; i.e., Brachionus, Keratella cochlearis, Filinia longiseta, Polyarthra, Synchaeta and Trichocerca, were rare or non-existent in the White River, whereas they are the dominant rotifers in other rivers (Eddy, 1932, 1934; Pennak 1943; Williams, 1966). Hynes (1970) included Notholca and Euchlanis in this list as common members of the river plankton. Of these supposedly dominant river taxa, only Notholca and Euchlanis were of numerical importance in the White River.

The dominant taxa at the White River were littoral forms such as bdelloids, Cephalodella, Monostyla, Colurella, Lepadella, contracted monogononts, etc. This fauna is usually associated with a substrate on which they live and feed, is characteristic of ponds and marshes and is suggestive of the "erosional assemblage of streams" described by Cummins (1972). However, the species in the river are the same as those occurring in the Yellow Creek drainage system, indicating possible sources of recruitment, i.e., many small streams and irrigation canals which drain into the river. The low numbers in June (normally the peak period for rotifer densities) can be related to the flood conditions of May and June and the intolerance of rotifers to turbulence and silty conditions (Williams, 1966).

The paucity of ponds and lakes in the White River drainage system near the study area and the lack of quiet backwaters and pools in the river itself explain the low numbers of planktonic rotifers and limnetic Crustacea in the White River. The few limnetic copepods which did occur (calanoid copepodites

and Diaptomus species) were badly mangled, indicative of the effect of the river's turbulence. This effect has been reported by Galtsoff (1924), who found that one rapids area on the upper Missouri River destroyed 60% of the river's plankton. The occurrence of Cladocera such as Alona, Pleuroxus and Chydorus in the White River are as expected, because forms such as these with compact, rounded bodies are more prone to survive the turbulence of the river. However, as with rotifers, the crustacean fauna of the river was identical to that of the Yellow Creek drainage system, suggesting that the river zooplankton may be the product of tributaries like Yellow Creek.

A comparison of the zooplankton above, below and within the vicinity of the Yellow Creek confluence suggests few or no differences attributable to Yellow Creek. Species composition and total densities are very similar in all three areas, although in October - November 1974 and August - September 1975, the protozoan densities near Yellow Creek (Stations 28 and 29) were somewhat lower than either above or below the confluence. As this was mainly the result of high Centropyxis spp. densities, these protozoans may have settled out of the plankton in the relatively quiet backwater at Station 27, just above the confluence. No other major differences in zooplankton species composition or densities among the areas were observed.

In summary, the zooplankton fauna occurring in the studv area consisted almost entirely of species commonly associated with a substrate, the nature of the substrate being either macrophytes or stones, gravel, detritus, etc. This fauna included rhizopods, protozoans, littoral rotifers, chydorid cladocerans, harpacticoid copepods (all herbivores) and cyclopoid copepods (predominantly carnivores). The most important factor controlling the distribution of these taxa (directly or indirectly) was temperature. Peak densities and number of species for rotifers and cladocerans occurred during the summer months, associated with warmer temperature and increased periphytic growth. Maximum densities of the predaceous cyclopoids can be related to the increased abundance of their food, i.e., the rotifers and cladocerans. Only the harpacticoid copepod Bryocamptus hiemalis and the rotifer Notholca were restricted to either the winter months or the cooler water of the spring brooks. Zooplankton

densities were generally lowest in the White River where there was a paucity of potential sources of recruitment such as lakes, ponds and quiet backwater areas.

C. Periphyton

1. Objectives - Periphyton studies are conducted to determine the species composition and standing crops of the periphyton communities to further aid in the characterization of the aquatic habitats on and near Tract C-a.

2. Methods - Six samples were collected at each station from natural substrates. Three of these were used to estimate abundance and three were used to determine biomass. Periphyton samples were collected from rocks that were relatively flat, which faced the surface of the water, and which were positioned at mid-depth in riffles. Rocks were carefully removed from the streams and periphyton was removed from a 50 cm^2 (7.7 in^2) area with a toothbrush and knife. Samples were stored in 4 oz jars containing 5% formalin until processing.

During the May - June, July - August and August - September 1975 sampling periods an additional set of three replicate 50 cm^2 (7.7 in^2) periphyton samples were collected from natural substrates for chlorophyll a determinations. Also during these sampling periods, three replicate samples, each representing a 38 cm^2 (5.9 in^2) area, were taken from artificial substrates (glass slides) at six stations (20, 21, 23, 27, 29 and 35). From these artificial substrate samples, cell density, biomass and chlorophyll a were determined. Laboratory methods are described in Section 8.2C of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976).

3. Data Summary and Discussion - The term periphyton refers to the benthic algal community; this community includes two major types of periphytic algae: attached and unattached. Unattached algae, such as some members of the genera *Navicula*, *Nitzschia*, *Surirella* and *Pleurosigma*, live on or in the substrate, but cannot move or are only weakly mobile. Attached algae, such as members of the genera *Cymbella*, *Achnanthes*, *Cocconeis*, *Gomphonema* and numerous filamentous green algae are found attached to the substrate by secreted gelatinous stalks, filaments or specialized basal attachment cells. Unattached algae can be more easily washed away in spates, while attached algae can

maintain their position in higher flows. Thus, attached algae are often dominant in winter and spring during periods of high flow, while unattached algae may be more common in summer during periods of low flow. Site specific data concerning composition and abundance of periphyton are given in Section 8.2C of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976). The following discussion presents analyses and interpretations of those site specific data.

Headwater stations may be characterized as alkaline spring brook seepage areas. Achnanthes minutissima, Navicula cryptocephala and Nitzschia frustulum were the most abundant algae at most headwater stations throughout the year; although at Station 1, Bicoeca lacustris dominated during May - June, July - August and August - September 1975.

Achnanthes minutissima is an indicator of high oxygen concentrations in alkaline waters (Lowe, 1974) which were characteristic of the headwater sites throughout the year. Both algal cell density and organic weight peaks (Table 3-8-15) occurred in December 1974 - January 1975 and were probably due to one or a combination of several chemical parameters that peaked at this time (calcium, sulfate, nitrate - nitrogen and hardness).

Navicula cryptocephala and Nitzschia frustulum were other common to abundant diatoms (of the headwater stations) that are considered periphytic, alkaliphilous species with an optimum pH around 8 (Lowe, 1974).

Bicoeca lacustris is considered a temporarily or permanently sessile flagellate and is enclosed in a delicate shell. Its ecology is insufficiently known, but members of the family are known to live on organic substances set free through bacterial decay (Grell, 1973). It was most abundant at Station 1 which often contains a substantial quantity of aspen leaves, which may encourage this species.

The tract stations (6 - 18) may be considered alkaline spring-brook areas. Periphyton cell densities were generally low, ranging from a mean low of 2,359

Table 3-8-15. Standing crop estimates of periphyton during RBOSP Aquatic Baseline Studies between October - November 1974 and August - September 1975.

		Headwater Stations (1-5)	Tract Stations (6-18)	Lower Yellow Creek Stations (19-22) Natural Substrates	Lower Yellow Creek Stations (19-22) Artificial Substrates	White River above confluence with Yellow Creek (23-27) Natural Substrates	White River above confluence with Yellow Creek (23-27) Artificial Substrates	White River at confluence with Yellow Creek (28-29) Natural Substrates	White River at confluence with Yellow Creek (28-29) Artificial Substrates	White River below confluence with Yellow Creek (30-35) Natural Substrates	White River below confluence with Yellow Creek (30-35) Artificial Substrates
Oct-Nov 74	Cell density[1]	3,128	4,453	11,127		15,970		10,223		14,839	
	Organic weight[2]	3.1	55.2	127.0		71.9		77.3		41.7	
Dec 74-Jan 75	Cell density	13,978	7,773	17,038		21,617		7,881		14,258	
	Organic weight	34.3	62.9	103.4		131.1		56.0		721.2	
April 75	Cell density	6,963	6,120	4,273		17,582		10,694		8,927	
	Organic weight	14.9	16.6	77.3		102.5		65.1		68.5	
May-June 75	Cell density	3,247	2,359	6,403	3,037	3,432	116	2,203		2,722	
	Organic weight	12.3	6.9	56.7	3.9	73.0	2.4	22.5		23.1	
	Phytopigment[3]	8.0	9.0	19.0		31.0		17.0		23.0	
July-Aug 75	Cell density	725	5,053	2,106	318	6,183	1,970	7,865	1,496	28,113	1,148
	Organic weight	9.3	10.1	33.1	3.7	35.1	5.4	14.3	3.7	18.5	2.3
	Phytopigment	8.0	13.0	20.0		59.0		43.0		37.0	
Aug-Sept 75	Cell density	1,774	7,846	1,993	975	33,936	9,396	9,318	10,857	26,322	8,915
	Organic weight	7.3	8.2	9.9	3.8	63.7	7.0	36.2	14.2	51.1	9.6
	Phytopigment	9.0	20.0	22.0		292.0		130.0		218.0	

[1] $Cells/mm^2$
[2] $Grams/m^2$
[3] Mg chlorophyll a per m^2

cells/mm^2 in May - June to 7,846 cells/mm^2 in August - September 1975. Achnanthes minutissima, Navicula cryptocephala and Nitzschia denticula were the most abundant species throughout the year. The ecology of Achnanthes minutissima and Navicula cryptocephala has been discussed earlier. Their abundance can be expected because of the similarity of physical and chemical parameters between the tract and headwater stations. Nitzschia denticula is an alkaliphilous species (best development at pH 8.2 - 8.5) and occurs in high oxygen concentrations (Lowe, 1974).

Station 14, located just below a small manmade pond, had generally higher periphyton cell densities than the other tract stations. During the winter, spring, and summer, Nitzschia denticula developed noticeably higher cell densities at this station. Synedra ulna, Nitzschia frustulum, Cymbella affinis and Navicula viridula also tended to flourish in this habitat. These species were not endemic to the station as they occurred in reduced numbers at upstream and surrounding stations. Although the current velocities varied throughout the year, the consistent species composition differences may have been due to the higher sulfate, magnesium, hardness and dissolved solids which occurred at Station 14 during the year.

Organic weights of samples from the tract stations were high in December 1974 - January 1975 and April which coincided with high mean cell densities of the tract stations. Gomphonema intricatum and Nitzschia denticula, two relatively large diatoms, were fairly abundant at this time and probably accounted for the higher organic weights.

The lower section of Yellow Creek (Stations 19 - 22) can be described as slightly brackish due to very high alkalinity and high conductivity. It also has large quantities of dissolved organic matter. Two general habitat types exist among the sampling stations; the lower stations (20 - 22) have similar stream conditions, while further upstream, Station 19 was sampled just below a pond habitat. The differences between the habitats were reflected in the species composition of the periphyton communities. Achnanthes minutissima, Fragilaria vaucheriae, Cyclotella meneghiniana, Navicula pelliculosa, Cymbella

affinis and Calothrix spp. tended to have higher densities at the lower stations (20 - 22). Rhopalodia gibberula, Nitzschia denticula, Nitzschia frustulum, Navicula cryptocephala and Navicula sp. tended to have higher densities at Station 19. The abundant species of both areas were alkaliphilous taxa (Lowe, 1975) and both areas had similar total periphyton cell densities. The species composition differences between these two areas were probably due to the higher magnesium, sulfate and total hardness concentrations which occurred at Station 19, in addition to the pond which may have contributed certain taxa. Unlike the above results, Dickman (1973) noted slight increases in blue-green algae in a stream to which bicarbonate was added.

The highest organic weight of periphyton at the lower Yellow Creek stations (19 - 22) occurred in May - June, 1975, while the highest cell densities occurred in December 1974 - January 1975. The slight organic weight peak of May - June 1975 was probably due to the fairly high number of filamentous blue-green algae and the larger diatom species which occurred on this date.

The artificial substrates at Stations 20 and 21 were dominated by Achnanthes minutissima which was also abundant in samples from the natural substrates. The total cell densities of the artificial substrates tended to be lower than those of the natural substrates, probably due to the lower surface area per unit sampled on the glass slides as opposed to rough rocks.

The White River Stations 28 and 29 usually had lower cell densities than those of the stations above and below the Yellow Creek confluence. Species composition of all the White River stations were similar except for several stations where Bicoeca lacustris became abundant in May - June and July - August. The floristic similarities were expected as the physical and chemical parameters were very similar at all the White River stations.

The most abundant diatom of the White River stations was Epithemia sorex, which developed highest densities during late summer and fall. Lyngbya spp., Calothrix spp., Nitzschia dissipata, Nitzschia frustulum, Navicula salinarum var. intermedia, Navicula cryptocephala and Amphora ovalis var. pediculus

are other alkaliphilous taxa (Lowe, 1975) that were abundant components of the White River periphyton communities. Total periphyton densities of the White River were low in May - June and July - August, which may be related to the scouring that undoubtedly occurred during the flood conditions of May - June. Amphora ovalis var. pediculus was dominant during May - June and July - August which may indicate it was the initial colonizer during and after scouring of the periphyton.

A comparison of the periphyton above, below and within the vicinity of the Yellow Creek confluence suggests few differences attributable to Yellow Creek. Species composition was very similar in all three areas, although cell densities were lower at the Yellow Creek confluence, which was probably due to lower current velocities and less suitable periphyton habitat.

The species composition of the artificial substrates on the White River generally compared favorably with those from the natural substrates, although cell densities were always lower on the artificial substrates. The only White River artificial substrate collected in May - June was dominated by Gomphonema olivaceum (with only 59 cells/mm^2) which was not abundant on the natural substrates. This species was probably able to remain attached to the artificial substrates during the flood conditions of May - June since it is a stalked diatom. Gomphonema olivaceum may be considered an early colonizer of clean glass substrates (Owen, 1973), possibly indicating that spring flood waters scoured the substrates bare, while the more protected natural substrates may not have been as disturbed. The species composition of the artificial substrates during July - August and August - September, 1975, was similar to the respective natural substrates, although cell densities were reduced in comparison to the natural substrates.

Diversity indices measure the complexity of a biotic community by considering the number of species or species richness and the equitability of distributions among the species. High diversity is frequently considered to be an attribute of stable communities, in which major population fluctuations do not occur. Diversity indices of the present study do provide some insight into peculiarities

of the system under investigation. The most obvious trend is for lower diversities in the whole Yellow Creek watershed (annual mean Shannon index = 2.00) than in the White River (annual mean Shannon index = 2.92). This may be attributed to several factors: 1) the input of algae from more diverse sources in the White River; 2) the generally higher current and more suitable substrates in the White River; and 3) the chemically and physically harsher environment of the Yellow Creek watershed.

Specific diversity differences in the Yellow Creek watershed may often be attributed to nearby sources of water or the presence of unusual habitats. The low diversities of Station 1 periphyton communities, (0.46 to 2.34) for example, may be attributed to the proximity of the sampling site to the spring source of water. Complexity of habitat and availability of a diverse upstream seed source are limiting in such a situation.

The outstandingly high diversities at Station 19 (2.92 to 3.37) are a function of the unique flora of the station. Rather than attribute the latter solely to chemical factors, the proximity of a pond with unique habitat may also be important. This pool, due to its extensive _Chara kieneri_ growths, undoubtedly promotes the growth of taxa not likely to thrive in the more rapidly flowing sections of the stream.

In general, the diversity indices tended to reflect the greater complexity and stability of White River periphyton over those communities of the Yellow Creek watershed.

All but one of the organic weights from the RBOSP study were within the range of biomass values determined by four authors cited in Cushing (1967). The mean organic weight of Stations 30 - 35 in December 1974 - January 1975 was three times higher than the higest value obtained by McIntire _et al._ (1964). Contrary to the results of Pennak (1974), Yellow Creek stations supported substantial periphyton standing crops.

Chlorophyll _a_ standing crops from the present study were within the range reported by six authors who used natural or artificial substrates to measure

periphyton productivity (Cushing, 1967). Chlorophyll a standing crops of the Yellow Creek watershed were usually lower than those of the White River. White River chlorophyll a standing crops were similar to those reported by Owen (1973) in the Columbia River.

Periphyton standing crops, as measured by numbers, biomass and phytopigments, tended to be lower at the headwater and tract stations while the higher standing crops usually occurred in the White River stations. The Yellow Creek stations usually had standing crops that were intermediate between the headwaters and the White River.

Many of the dominant and abundant periphyton taxa found on the RBOSP site are cosmopolitan species which are common in alkaline waters. Common to abundant species that have been found at both the RBOSP site and in similar hardwater streams were Achnanthes lanceolata, Achnanthes minutissima, Cocconeis placentula, Navicula cryptocephala, Navicula viridula, Cymbella ventricosa, Gomphonema intricatum, Gomphonema parvulum, Gomphonema olivaceum and Nitzschia palea (Butcher, 1946; Foged, 1947 - 1949, cited in Round, 1957). Lowe (1974) noted that Achnanthes minutissima, Cymbella ventricosa, Gomphonema parvulum and Nitzschia palea (species common on the RBOSP site) were indifferent to pH.

Kosloucher and Minshall (1973), in a study of a similar stream habitat, found Diatoma, Epithemia, Gomphonema, Navicula, Nitzschia, Cocconeis and Meridion as common all year. Abundant diatoms from the White River in December - January were Epithemia sorex, Diatoma vulgare and Nitzschia dissipata. At other collection dates, Epithemia sorex, Navicula cryptocephala, Navicula salinarum var. intermedia, Navicula viridula, Nitzschia dissipata, Nitzschia frustulum and Amphora ovalis var. pediculus were abundant at the White River stations, indicating a degree of similarity.

In summary, the diatoms dominated periphyton communities in all waters of the study area. Periphyton standing crops tended to be highest in the White River and lowest in waters near the tract and headwater areas; standing crops in Yellow Creek were intermediate. In general, the species diversity of the

periphyton community reflects the complexity of the community and its stability. The highest periphyton species diversities occurred in the White River. The factors which account for this higher diversity include generally greater current velocities and more suitable substrates in the White River and the chemically harsher environment found in other areas. Differences in diversity in the headwaters, tract and Yellow Creek areas may often be attributed to the proximity to a diverse upstream seed source (the low diversity in the spring at Station 1 was attributed to the absence of such a seed source) or the presence of unusual habitats (the high diversity in the spring at Station 19 is related to its proximity to a pond habitat as well as the unique chemical characteristics of the waters). The same factors which account for the higher diversity of periphyton in the White River also undoubtedly account for the greater standing crops observed there. In general, the species composition of all habitats investigated reflected the alkaline condition of the waters of the region.

The periphyton constituted the major source of autochthonous primary production in all waters of the region and, as such, would serve to indicate trends at the primary producer level during the monitoring phase.

D. Benthos

1. Objectives - The objective of the benthos (macroinvertebrate) studies is to describe the benthic community at each sampling station. This includes taxonomic composition, abundance of these described taxa, and species diversity indices.

2. Methods - At each station, triplicate samples were collected using a modified Surber sampler, an Ekman grab, or a D-frame sampler. In most cases the modified Surber sampler was used. It was proven to be effective in rubble and gravel substrates, and gives quantitative results. The Ekman grab was used at pool Station 14. On several dates it was impossible to collect benthos with conventional quantitative means at certain White River stations. This was due to the water depth, type of substrate, and high current velocities. At such times the D-frame sampler (used as a kick net) was used; this sampler gives only qualitative results.

At times, seasonal changes in conditions in the White River increased the difficulty of benthic sampling. In winter, low temperatures brought about flowing slush and ice blocks. Spring floods from snow melt caused the river to overflow its banks. Both of these situations caused benthic sampling to be perilous and, at best, extremely difficult.

After collection, benthos samples were washed in buckets with bottoms fitted with a U.S. Standard No. 30 sieve, and preserved with neutralized 10% formalin. Laboratory methods are described in Section 8.2D of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976).

3. Data Summary and Discussion - Benthic invertebrates represent those organisms which live on or in the interstices of the bottom substrates. River and stream benthic fauna are considerably different from lake benthic fauna. In river systems, the aquatic insects are the major components of the fauna. Many groups of benthic organisms are restricted to flowing waters. Site specific data concerning composition and abundance of benthic

organisms are presented in Section 8.2D of the Environmental Baseline Studies Annual Report for 1975 (RBOSP, 1976). The following discussion presents analyses and interpretations of those site specific data.

The organisms most often encountered throughout the Yellow Creek drainage were the Diptera (Chironomidae, Simuliidae, Ceratopogonidae, Tipulidae and Anthomyiidae), Oligochaeta, Ephemeroptera (Baetis), Plecoptera (Capnia), Trichoptera (Hydroptilidae and Hesperophylax), Odonata (Coenagrionidae), and Coleoptera (Dytiscidae). Organisms occasionally collected in the Yellow Creek drainage were Ephemeroptera (Callibaetis and Caenis), Diptera (Psychodidae, Stratiomyidae, Tabanidae and Emphididae), Gastropoda, Hirudinea (Helobdella stagnalis) and Hyallela azteca. Benthic invertebrates collected rarely in the Yellow Creek drainage were Ephemeroptera (Epeorus and Tricorythodes), Odonata (Aeshnidae and Gomphidae), Plecoptera (Perlodidae), Hemiptera (Corixidae, Notonectidae and Gerridae), Coleoptera, Gyrinidae, Haliplidae, Hydraenidae, Hydrophilidae, Elmidae and Dryopidae), Trichoptera (Hydropsyche and Grammotaulius), Diptera (Thaumaleidae and Dixidae), Hydra and Collembola.

In the White River, the Ephemeroptera, Diptera and Oligochaeta were the dominant groups. There was a greater diversity in the mayflies, caddisfiles and stoneflies in the White River than in any of the other sampling areas. Ephemeroptera included primarily Ephemerella, Rhithrogena and Baetis. Moderate numbers of Heptagenia and Tricorythodes were observed, while Ameletus, Lachlania, Centroptilum, Dactylobaetis, Paraleptophlebia, Caenis, Brachycercus and Ephoron were rare. Also in the White River, the Chironomidae were generally less abundant than in areas of the Yellow Creek drainage.

The caddisflies most often encountered were the Hydropsychidae. Taxa of Hydroptilidae and Glossosomatidae were occasionally observed, while Oecetis and Brachycentrus were rare. The most common Plecoptera were Isogenoides, Isoperla and Claassenia. Brachyptera and Capniidae were occasionally collected. Small numbers of organisms belonging to other insect groups were also encountered in the White River; the other insect groups included: Odonata (Ophiogomphus), Lepidoptera (Pyralidae), Acari, Collembola, Hemiptera

(Corixidae), Coleoptera (Elmidae) and Diptera (Ceratopogonidae) Tipulidae, Simuliidae, Rhagionidae and Empididae.

The Oligochaeta observed in all sampling areas were represented by seven families: Tubificidae, Naididae, Enchytraeidae, Lumbriculidae, Haplotaxidae, Lumbricidae and the Aeolstomatidae.

In general, the Naididae and Enchytraeidae were abundant in the headwater and tract regions, whereas the Tubificidae and Naididae were abundant in Yellow Creek and the White River. The family Naididae, which was generally abundant throughout the study area, has been characterized by Brinkhurst (1966a) as occurring in rapidly flowing streams. Howmiller and Beeton (1970) reported that these small, fragile worms occasionally pass through the mesh sieves used in benthic surveys and therefore, not all potential species are reported. The family Enchytraeidae was most common in the tract region. According to Brinkhurst (1953), most species belonging to this family are terrestrial in habit; this fact suggests that their abundance in the tract region can probably be attributed to their ability to survive during the period in which the streams remain dry. The Tubificidae, long characterized as being tolerant of environmental stress (Brinkhurst and Jamieson, 1971) were abundant at Station 5 of the headwater region and in Yellow Creek and the White River. Tubificids are known to feed primarily upon bacteria associated with organic matter (Brinkhurst et al., 1972). The relatively great amount of aquatic vegetation at Station 5 suggested that there was abundant organic matter available for bacterial decomposition which, in turn, provided abundant nutrients for tubificids. However, the reasons for the abundance of tubificids in other regions are unknown. The family Lumbriculidae occurred in the tract region, in Yellow Creek, and in the White River. This group has previously been characterized as occurring in stony trout streams. In the present study, the family Lumbriculidae was represented by specimens possessing a thick muscular body wall and two setae per bundle indicating that these specimens may belong to the genus Sparoanophilus which has been reported as the most common limnetic megadrile in North America (Brinkhurst and Jamieson, 1971). The family Haplotaxidae occurred only in the headwater

region; these organisms have been reported primarily from underground waters and in areas where ground water seepages enter a stream (Brinkhurst, 1966a, b). A single specimen of the family Aeolostomatidae was collected during the present studies. These worms are fragile, less than 2 mm (0.08 inches) long and are not generally found in benthic collections unless special attention is given to them (Brinkhurst and Cook, 1974.)

The assemblage of macroinvertebrates in the Yellow Creek drainage was represented by a diverse number of taxa which are well adapted to the conditions of the biotic environment. This was particularly true for many of the taxa which occur in the White River. Dorso-ventral flattening, for example, was common in many mayflies and stoneflies. Rhithrogena, Heptagenia, Choroterpes, Traverella albertana of the mayflies and Claassenia sabulosa, a stonefly, have this structural adaptation. With this adaptation, these organisms can remain within the Prandtl or boundary layer (Jaag and Ambhl, 1964) and move about actively without being dislodged from the substrate. In the genus Rhithrogena, the first and seventh pairs of gills have been modified to increase the area of marginal contact. According to Hynes (1970) this reduces possibility of the waters flowing under the nymph. Other mayflies, such as Caenis, Tricorythodes and Brachycercus, have the second pair of gills modified into opercula-like covers. These taxa live on highly silted areas and the modified gills protect the other gill pairs on segments 3 to 6. The extremely abundant blackflies are equipped with a rear circlet of hooks which attach under silk lines (produced by the salivary glands) that are fastened to the substrates. The proleg of simuliids also have a circlet of hooks to aid in movement.

Many of the adaptations of aquatic insects in the Yellow Creek drainage and in the White River were related to their food gathering habits. All feeding types were represented in the fauna of the drainage. While many of the taxa were filter or net feeders, others were detritivores, which aid in the breakdown of allochthonous and autochthonous materials in the system. Many of the taxa were opportunistic feeders and were therefore difficult to classify.

The benthic fauna at headwater Stations 1 - 4 was similar but this fauna differed from that of headwater Station 5. Physico-chemical factors help explain this difference. Station 5 was located downstream from a weed choked (sedges and watercress) spring area while Stations 1 - 4 were typified by cool springs with relatively little macrophytic growth. The stream beds at Stations 1 - 4 were composed of loose aggregations of sand, gravel and shale pieces covered with periphyton. The substrate at Station 5 was thoroughly compacted gravel with the periphyton bound in a small incrustation. The number of taxa and the density of organisms was generally higher at Station 5 than at the other four stations. Available food supply, substrate type and differences in dissolved solids (higher at Station 5) were the probable reasons for the differences in community structure.

The aquatic insects of the headwater stations have univoltine (one generation/year) or multivoltine (more than one generation/year) life cycles. The aquatic insects which take two or three years for development have not been successful in the invasion of the headwater stations. The Ephemeroptera, (composed primarily of Baetis) reached peak abundance at Station 4 in December 1974 - January 1975. By May - June 1975, the densities had decreased dramatically, most likely due to emergence of the insects. Emergence of the Capnia spp. occurred in late winter and early spring. These stoneflies have univoltine life cycles as do the few trichopteran genera found in these headwaters. Because of the occurrence of many genera of dipterans, their emergence patterns were difficult to define. The Simuliidae (blackflies) have been described in the literature as possibly having multivoltine life cycles (Hynes, 1970).

Tract stations (6 - 18) tended toward more temporary flow than other stations within the Yellow Creek drainage. Stations 10, 11 and 16 have been dry throughout the study. These stations were located in large gulches, which were wet during periods of rain and heavy runoff from snowmelt. Stations 6, 12, 15 and 18 were flowing only once during the sampling periods. Station 17 was flowing on two collection dates. The fauna of these intermittent stations was represented by species with rapid life cycles, and species which can easily invade new waters by various means. Thus, the adults may deposit eggs

or the immature stages may drift downstream or actively move upstream. During drought periods the fauna may burrow into the loose substrates (hyporheic zone and exist in a dormant stage until conditions improve.

The substrates at tract Stations 6 through 13, and 14, 17 and 18 were generally similar and were composed of gravel, sand and silt. Because the substrates and chemical conditions at these stations were generally similar, these stations resembled headwater Stations 1 through 4 more than any other group of stations. While the densities of certain taxa remained hight, the number of species was generally lower at the tract stations than at the headwater stations (the annual mean Shannon indices for the headwater and tract stations were 1.85 and 1.87, respectively). Drought conditions at the tract stations are believed to be one of the major reasons for this. Station 14 was a pond area partially filled with the aquatic macrophyte Zannichellia palustris. The components of the benthos at this site were Corixidae, Dytiscidae, certain Chironomidae such as Micropsectra, Ceratogoponidae and Anthomyiidae; Naididae and Enchytraeidae were the common aquatic worms. Seasonal patterns of the macroinvertebrates at the tract stations were very similar to those described for the headwater Stations 1 - 4.

Lower Yellow Creek (Stations 19 - 22) was characterized by high dissolved solids. Station 19 had slightly lower specific conductivity and alkalinity than Stations 20 - 22. The findings of the present study at Station 20 are comparable with those of Pennak (1974). However, his statement that "three of the four common orders of stream insects (mayflies, caddisflies and stoneflies) are absent from the Yellow Creek, undoubtedly as a result of exceptionally high salt content of this water" is not completely substantiated. It is true that the abundance of these common stream insects was extremely low in the location that Pennak sampled over a corresponding time period. However, upstream at Station 19, where dissolved solids were slightly lower (but nevertheless extremely high), these common stream orders occurred in moderate numbers at certain times of the year. Station 19 was located at a pool which is choked with Chara. The difference in substrate and the availability of food, and consistently cooler water temperatures at Station 19 were

probably some of the reasons for the higher number of species and greater species richness here than at the other Yellow Creek stations.

Densities of certain taxa were extremely high at the Yellow Creek stations. However, species diversity indices for these stations were quite low (annual mean Shannon Index = 2.52) due to dominance of a few taxa. High salt content was certainly one of the limiting factors in this creek.

The White River was characterized by a rubble bottom with many interstitial areas which were available as habitat for benthic organisms. Densities of macroinvertebrates were lower in the White River than in Yellow Creek drainage, but diversities were generally higher in the White River (annual mean Shannon Index = 2.83). This was due to the increased numbers of genera of mayflies, caddisfiles and stoneflies, and to the fact that there was less dominance by a few taxa. Insects were abundant in the White River and the major emergence occurred in late spring and early summer. Diversity indices for the White River stations indicated significant decreases in the Shannon-Wiener Index, richness and number of species in the July - August samplings.

Stations 28 and 29 were located in a side channel of the White River at the confluence with Yellow Creek. Station 28 was located directly off the mouth of Yellow Creek, and Station 29 was approximately 100 m (328 ft) downstream. Station 28 was unique among the White River stations in that the substrate was compacted gravel and sand, and flow was slow enough during low water periods to allow the area to silt over. This substrate change was reflected in the relatively low densities of Ephemeroptera, Plecoptera and Trichoptera compared to the other White River stations. A seasonal trend at Stations 28 and 29 was suggested by the occurrence of Ephemeroptera, Plecoptera and Trichoptera. Whether this was due to emergence patterns or the change in habitat is not clear. It is possible that the peak emergence occurred just prior to the periods of low flow and the area was recolonized, through drift, after it had been cleared of silt by higher flows later in the year.

The percentage of Oligochaeta was higher at Stations 28 and 29 than at the other White River stations. This was likely due to the higher amounts of silt available in this area.

Physically, the lower White River stations (30 - 35) were similar to the upper White River stations (23 - 27) except that the substrate was less consolidated at the lower stations. The percentage of Oligochaeta was noticeably less at these lower stations. This was likely due to the larger rocks and rubble having more surface area exposed to the current. Thus there was a constant shifting of the small particles which tended to inhibit burrowing organisms. In the White River stations, there was a greater diversity of mayflies, caddisflies and stoneflies than in Yellow Creek or at the tract and headwater stations. Diversity indices provided clues as to the life cycles and emergence periods of this fauna. The major reason for increased diversity in the White River was the additional habitats which were available.

During the summer growing periods, the periphyton was bound in a marl matrix which may have caused some problems for strictly herbivorous organisms. Most of the dominant organisms (Ephemerella, Hydropsychidae, Chironomidae, Oligochaeta and Plecoptera) probably avoided this problem by being omnivores, detritivores, filter feeders or predators (Berner, 1959; Ross, 1944; Pennak, 1953).

In summary, the headwater stations were represented by a moderately diverse benthic community which maintained high densities of organisms throughout the year. Diptera were abundant in the headwater stations as well as in the tract and Yellow Creek stations. However, diversities were lower at the tract and Yellow Creek stations. Fewer genera were found here, and certain taxa such as the Simuliidae were extremely abundant.

The diversity of the benthic community of the White River was higher than that observed in any of the other study areas. Benthic densities were moderate throughout most of the year. The Shannon Index, the number of species, and species richness were highest in the region above the confluence with Yellow

Creek. It appears that this is related more to substrate type and sampling location rather than to the influence of Yellow Creek since the mayfly, caddisfly and stonefly populations were comparable above and below the confluence with Yellow Creek.

Benthic macroinvertebrates were the dominant organisms at the primary and secondary consumer levels in most waters of the study area, and, as such should serve to indicate trends at these levels during the monitoring phase.

E. Macrophytes

1. Objectives - The objectives of this aspect of the RBOSP Aquatic Baseline Studies are to identify and enumerate aquatic macrophytes, to determine relative abundance of each species and to describe the major beds of macrophytes at each station.

2. Methods - Macrophyte data were collected using a random transect line system (Jessen and Lound, 1962). Samples were collected simultaneously with the field collection of other biological data.

Samples were taken along randomly chosen transects that cross the streams at each station. All plants within 0.5 m (1.6 ft) upstream and downstream of the transect line were identified and representative plants were maintained as voucher specimens.

The areas covered by major beds of macrophytes upstream and downstream of each site were measured with a tape while wading in the stream or pond. The major species in each bed was determined and relative abundance of those species was noted. The relative abundance of macrophytes at various sampling stations is provided in Table 3-8-16. Laboratory processing of macrophyte samples is described in Section 8.2E of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976).

3. Data Summary and Discussion - Site specific data concerning composition and abundance of aquatic macrophytes are presented in Section 8.2E of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976). The following discussion presents analyses and interpretations of these site specific data.

A summary of species composition and relative abundance of macrophytes is presented in Table 3-8-16. In general, aquatic macrophytes did not comprise a major component of aquatic ecosystems on or near Tract C-a. The aquatic macrophytes which were on or near Tract C-a were emergents and/or plants

Table 3-8-16. Relative abundance of macrophytes at aquatic sampling during RBOSP Aquatic Baseline Studies, October - November 1974 to August - September 1975.

Station	Date: Oct.-Nov.	Dec.-Jan.	April	May-June	July-Aug.	Aug.-Sept.
1				Watercress-1[a]		American Speedwell-1
2			Watercress		American Speedwell-1	American Speedwell-1
					Shore crowfoot-2	
3					American Speedwell-2	Shore Crowfoot-2
4						American Speedwell-1
5		Unknown Sedge		American Speedwell-3	Horned Pondweed	American Speedwell-2
				Shore Crowfoot-	Shore Crowfoot-1	Shore Crowfoot-4
				Watercress-1	Watercress-	Watercress-2
				Manna Grass-3	Water Crowfoot-2	
7						Shore Crowfoot-2
8		Pondweed	Unknown Grass	Unknown Grass-3		
		Watercress	Watercress	Watercress-2		
9	Horned Pondweed					Shore Crowfoot-1
10	Watercress					
	Mares Tail					
14	Stonewort		Horned Pondweed	Horned Pondweed-3	Horned Pondweed-4	Horned Pondweed-5
19			Stonewort (dead)	Stonewort-5		Stonewort-5
						Shore Crowfoot-2
						Horned Pondweed-2
						Three-square
20				Horned Pondweed-4		Horned Pondweed-4
						Three-square-3
						Bayonet-grass-3
21						Horned Pondweed-4
						Three-square-3
						Bayonet-grass-3

[a] Number indicates relative abundance of plants as provided in Jessen and Lound, 1962.
5 (most abundant) 2 scattered growth
4 heavy growth 1 (least abundant)
3 moderate growth

typical of moist to wet alkaline habitats. Plants more typical of alkaline ponds included bayonet-grass, stonewort, shore crowfoot and horned pondweed. Although many of the other species may occur in wet alkaline habitats, they are more cosmopolitan and occur in a variety of marshy habitats (i.e., American speedwell, three-square and manna grass). These three species range throughout most of the U. S.

F. Fish

1. Objectives - The objective of this study is to describe the fish community of the study area by collection and identification of fishes, pertinent meristic measurements, and observations of growth, spawning and condition.

2. Methods

a. Field Sampling - White River - The primary method of sampling in the White River was electrofishing with a 220 volt, 1,000 watt AC/DC electrofishing unit. The alternator and electrofishing unit were placed on shore and connected to two hand held probes (positive and negative) at the ends of 15 m (50 ft) lengths of waterproof cable (two positive probes were used at some stations in April). AC voltage was used in October 1974 and DC voltage at all other times.

Approximately 100 ft sections of stream were sampled. The probes were moved upstream where possible, and sometimes downstream. Stunned fish were picked up with dip nets. Early attempts at holding seines below the probes while moving downstream were unsuccessful due to the extreme difficulty of holding the seine against the current. Each station was sampled twice. Back channel areas at Stations 23, 27 - 29 and 33 were blocked off during sampling with 0.64 cm (0.25 inch) square mesh seines during low flow periods in October - November 1974, April, July - August and August - September 1975.

b. Field Sampling - Yellow Creek - Yellow Creek Stations 20 - 22 were completely blocked off with seines. When sufficient water was flowing, two seine hauls were made through 30 m (100 ft) sections in an upstream direction. During summer and fall low periods, the stations were sampled in duplicate with dip nets.

c. Sample Processing (Field) - Captured fish were held in 0.137 cm (0.124 inch) mesh holding nests (large fish) or buckets of water (small fish) until one or more stations had been sampled. The larger fish were then weighed

to the nearest gram and measured (total length) to the nearest millimeter. Stomachs were excised from some of the larger fish and placed in individual jars in 10% formalin. Some smaller fish were preserved whole in 10% formalin for laboratory processing. Scales were taken from appropriate species and placed in individual envelopes on which all pertinent data were recorded. Certain larger fishes were preserved whole for inclusion in a voucher collection.

d. Sample Processing (Laboratory) - Fishes returned to the laboratory were weighed to the nearest 0.1 g and measured to the nearest mm. Identifications were confirmed with the aid of taxonomic keys that included Beckman (1952), Smith (1966) and Minckley (1973).

Fish stomachs brought back from the field and those taken from smaller fish in the laboratory were cut open and the contents were examined under a dissecting microscope. The total number of each food item was obtained, either by a complete count, a sub-sample count or, for numerous small organisms, an eye estimate and recorded separately for each fish. Identifications of food items were made to the lowest possible taxonomic level.

Fish scales were stained with Alizarin Red S, permanently mounted on glass slides and examined under either a microprojector or a dissecting microscope. The criteria of Tesch (1968) were used to determine the presence of annuli (year marks). Number of annuli and distances from each mark to the scale focus were recorded.

Length-frequency analyses were done on flannelmouth suckers, mottled sculpin and speckled dace by the method described in Lagler (1956).

Condition factors (K) were computed from the formula given by Carlander (1969):

$$K = \frac{W\,10^5}{L^3}$$

where W = weight in grams

L = total length in millimeters

and 10^5 = a factor to bring near unity.

3. Data Summary and Discussion

a. Fish Community Composition

1) General - A total of 15 fish species and one hybrid form were captured in the White River and Yellow Creek during RBOSP aquatic studies. The most common species were flannelmouth sucker, bluehead sucker, speckled dace, fathead minnow and mottled sculpin (Table 3-8-17). The small number of species captured is similar to findings of other studies. Holden and Stalnaker (1975b) reported 29 species in the Middle and Upper Colorado River Basins. McDonald and Dotson (1960) reported 17 species in the Glen Canyon area of the Colorado and San Juan Rivers and 16 species in the Flaming Gorge area of the Green River. In the White River, Pettus (undated) reported eight species and Everhart and May (1973) reported 12 species.

The fish fauna west of the Rocky Mountains and north of Mexico was characterized as "depauperate" by Miller (1961). Approximately 100 species are known from the region. Behnke (unpublished manuscript) listed 27 species as native to the Colorado River Basin. "Species diversity" is indeed low when compared to the Illinois River (92 species) or the Black River, Missouri (68 species) (Hynes, 1970).

Introduced species have increased tremendously in the western United States in the last 100 yr. Minckley (1973) pointed out that the original eight or nine families of fishes native to Arizona have increased to 22, or almost one-half of the number of strictly freshwater fish families recorded in the entire U. S. The results can be seen in data from various studies in the Middle and Upper Colorado River Basin:

Source	Number Native Species	Number Introduced Species
Holden and Stalnaker (1975a)	10	19
Vanicek, et al. (1970)	9	12
McDonald and Dotson (1960)	6	11
McDonald and Dotson (1960)	9	7

Table 3-8-17. List of fish species and numbers captured at the RBOSP site during the period October 1974 through September 1975.

Common Name[1]	Scientific Name[1]	Numbers Captured					
		October 1974	April 1975	June 1975	July 1975	September 1975	Total
Cutthroat trout	*Salmo clarki*	-	-	1	-	-	1
Brown trout	*Salmo trutta*	1	1	-	-	1	3
Rainbow trout	*Salmo gairdneri*	1	4	-	-	-	5
Mountain whitefish	*Prosopium williamsoni*	7	2	-	-	8	17
Roundtail chub	*Gila robusta*	-	1	10	5	5	21
Speckled dace	*Rhinichthys osculus*	126	21	238	48	392	825
Fathead minnow	*Pimephales promelas*	90	10	54	5	150	309
Red shiner	*Notropis lutrensis*	-	-	-	1	10	11
Carp	*Cyprinus carpio*	-	-	1	3	23	27
Flannelmouth sucker	*Catostomus latipinnis*	58	66	128	109	162	523
Bluehead sucker	*Catostomus discobolus*	26	14	38	17	64	159
Mountain sucker	*Catostomus platyrhynchus*	-	-	-	1	1	2
Channel catfish	*Ictalurus punctatus*	-	-	-	-	1	1
Black bullhead	*Ictalurus melas*	-	-	-	1	-	1
Mottled sculpin	*Cottus bairdi*	233	28	11	11	130	413
Flannelmouth X Bluehead	*Catostomus lattipinnis* X *C. discobolus*	-	1	-	-	2	3

[1] Common and scientific names after Bailey, et al. 1970

Source	Number Native Species	Number Introduced Species
Miller (1964)	8	7
Everhart and May (1973)	7	5
Pettus (undated)	5	3
Present RBOSP Study	8	7

2) Family Salmonidae - Cutthroat trout, *Salmo clarki* (native) - One adult specimen was captured at Station 29 near the mouth of Yellow Creek in June, 1975. The single occurrence of this species, and also the low numbers of brown and rainbow trout, is most probably due to marginal habitat conditions i.e., high silt load and elevated summer water temperatures. Although cutthroat trout are native to the Upper Colorado River, the original native subspecies, *Salmo clarki pleuriticus*, is very rare (Behnke, unpublished manuscript The specimen captured in the White River was most probably *Salmo clarki lewisi*, a widely introduced form.

Brown trout, *Salmo trutta* (introduced) - Three brown trout were captured, one each at Stations 23, 28 and 29. Marginal habitat conditions probably restrict this species in the study area, although brown trout are reportedly more tolerant than other trouts to silt and high temperatures (Beckman, 1952).

Rainbow trout, *Salmo gairdneri* (introduced) - Five rainbow trout were captured; one in October, 1974, and four in April, 1975, at Stations 29 and 28 respectively. As with the other trout species, the small number of fish is due to marginal environmental conditions.

Of the nine trout of all species captured to date, eight were taken at or just below the mouth of Yellow Creek at Stations 28 and 29. The most plausible reason for this is the existence of more cover, i.e., undercut banks, brush piles, in this side-channel area compared to the main river (Stations 27, 28 and 29 are separated from the main river by an island).

As mentioned under the discussion of cutthroat trout, high summer water temperatures are considered one of the "marginal" habitat conditions for trout.

However, this is not a clear-cut phenomenon. White River temperatures during summer, 1975 (RBOSP 1976), and summer, 1973 (Pennak, 1974), ranged from 15 - 21^{0}C and 8.5 - 15.3^{0}C, respectively. These temperatures are within the preferred range of rainbow and brown trout (McAfee, 1966; Scott and Crossman, 1973). However, Everhart and May (1973) reported a maximum temperature of 24^{0}C for the White River in July 1969. This was in excess of the upper preferred temperature of rainbow trout and at the upper preferred limit of brown trout. It may be that the occasional high water temperatures, along with the silt load and competition from warm-water species, are enough to restrict trout populations in the study areas.

Mountain whitefish, Prosopium williamsoni (native) - Seventeen mountain whitefish were captured at various stations during October 1974 and April and September 1975. Most of these specimens were sexually immature age class I fish (see age-growth section). Little information can be derived about the mountain whitefish population because of the small catch. The small catch of this species may be due to the species preference for deep, fast runs, a habitat type which proved difficult to sample during the RBOSP studies. Goodnight and Bjornn (1971) cited this as the reason for their limited success in collecting mountain whitefish in the Lemhi River, Idaho.

3) Family Cyprinidae - Rountail chub, Gila robusta (native) - Specimens of roundtail chub were captured during every sampling except that in October - November 1974, relatively few fish were captured. The largest catch was 10 specimens in June 1975.

The roundtail chub is the "dominant native carnivore" of Colorado River tributary streams according to Holden and Stalnaker (1975b). These authors indicated the species was abundant in the White River, but gave no specific data. The species is widely distributed in the Colorado River Basin (Holden and Stalnaker, 1970) and is holding its own against introduced species, at least in Arizona (Minckley, 1973).

Speckled dace, Rhinichthys osculus (native) - This species was the most abundant species captured during the initial year of study. It was numerous in

White River near Piceance and Yellow creeks (Pettus, undated) and in the Middle and Upper Colorado River Basins (Holden and Stalnaker, 1975b).

Since RBOSP Progress Reports 2, 3 and 4, additional taxonomic study has shown that specimens previously identified as longnose dace, Rhinichthys cataractae, are instead, speckled dace, Rhinichthys osculus.

Fathead minnow, Pimephales promelas (introduced) - This species is not native west of the Rocky Mountains (Miller, 1952), but its popularity as a baitfish has apparently resulted in its introduction in many parts of the western U. S. The species was first reported from the Middle and Upper Colorado River Basins in the late 1950's and early 1960's and was reported common (but never abundant) throughout the area in 1967 - 1973 (Holden and Stalnaker, 1975b). Andrews (1971) reported the species widely introduced in western Colorado.

Over 300 specimens were captured during RBOSP Aquatic Studies, making it the fourth most abundant fish in the catch. In their 1969 sampling of Piceance Creek, the White River and Yellow Creek, Everhart and May (1973) recorded no fathead minnows. Four years later, Pettus (undated) reported four specimens, three in Piceance Creek and one in the White River. Notwithstanding the greater intensity of the RBOSP Baseline Study, the numbers of fathead minnows captured indicate a recent increase in the population in the study area.

Red shiner, Notropis lutrensis (introduced) - Only 11 red shiners were captured, one in July and 10 in September 1975, all near the mouth of Yellow Creek at Stations 27, 28 and 29.

The red shiner was reported from the White River near the present study area in 1969 by Everhart and May (1973), but was not reported by Pettus (undated) from a 1973 sampling. Holden and Stalnaker (1975b) reported that the red shiner was a recent introduction in the Upper Colorado River Basin and that it was extending its range up the Green River (Utah) during the period 1967 - 1973. They reported capturing one specimen in the White River.

Carp, *Cyprinus carpio* (introduced) - Twenty-seven specimens were captured during the study period, most of these were small (less than 100 mm (3.9 inches)) and were captured in September 1975.

Holden and Stalnaker (1975b) reported that carp was widely distributed in the Middle and Upper Colorado River Basins but it was generally not abundant. Neither Everhart and May (1973) nor Pettus (undated) reported the carp from the White River.

4) *Family Catostomidae* - Flannelmouth sucker, *Catostomus latipinnis* (native) - The flannelmouth sucker was the most abundant "large" fish captured during the period. Over 500 were captured, with numerous specimens being taken during each sampling period (Table 3-8-22). They were captured in every type of habitat, from swift, relatively deep runs to shallow runs over rocky substrate to mud-bottom pools. Greater numbers were captured in the latter habitat, probably due to greater sampling efficiency in these areas.

The flannelmouth sucker is one of the most widespread and abundant large fishes in the Colorado, San Juan and Green Rivers (McDonald and Dotson, 1960), Green River (Miller, 1964), Yampa and Dolores Rivers (Holden and Stalnaker, 1975a) and the Middle and Upper Colorado River Basins in general (Holden and Stalnaker, 1975b). The species was reported common in the White River near the present study area (Pettus, undated). Everhart and May (1973) recorded the species but gave no abundance data. Although the flannelmouth sucker is still a relatively widespread species in the Colorado River Basin, both Behnke (undated) and Minckley (1973) reported the species reduced in range, particularly in the lower basin. Minckley indicated that it is a "large-river" species and consequently has been reduced in the lower basin due to impoundments.

Bluehead sucker, *Catostomus discobolus* (native) - Smith (1966) reported this species widespread in the Colorado River System above the Grand Canyon. It also occurs in the Snake River drainage (Columbia River System) in Idaho and Wyoming, and in Bonneville Basin streams in Idaho, Wyoming and Utah. Beckman (1952) and Holden and Stalnaker (1975b) reported that the species prefers gravel bottom streams.

During the present RBOSP Baseline Studies, 159 bluehead suckers were captured. This indicates the species is common but not abundant. Smith (1966) did not list a single White River record (in Colorado) for the bluehead sucker on his species distribution map. However, rather than reflecting actual distribution it probably resulted from the dearth of research on the White River in Colorado. Most previous sampling and research emphasis has been on the mainstream Colorado River and other tributary streams. Everhart and May (1973) did not report the species from the White River. However, Pettus (undated) found it the most abundant large species in his catch in 1973.

Mountain sucker, Catostomus platyrhynchus (native) - Only two specimens of mountain sucker were encountered during the study period, one in July and one in September 1975.

The mountain sucker is widely distributed in the western U. S. and Canada, occurring in various drainages from California to British Columbia and east to Saskatchewan and South Dakota, and south to Utah (Smith, 1966). However, Smith gave only one record of the species in Colorado, in Piceance Creek, and indicated that it was the most isolated population of the species in the Colorado River Basin. Behnke (personal communication) indicated that no additional locality records for Colorado have been reported since Smith's (1966) report. Everhart and May (1973) reported the species in both Piceance Creek and the White River. Pettus (undated) encountered the species only in Piceance Creek.

The mountain sucker is usually an inhabitant of small mountain streams (Smith, 1966). Consequently, it has not appeared in data from studies of the Colorado River mainstream and major tributaries (e.g., Holden and Stalnaker, 1975b). The occurrence of the species in the White River near the RBOSP study area probably represents a few strays from the Piceance Creek population rather than an actual White River population.

5) Family Ictaluridae - Channel catfish, Ictalurus punctatus (introduced) - One adult channel catfish was caught during September 1975 at Station 27.

This species was introduced into the Colorado River system in the late 1800's, and it apparently became widely established by the early 1900's (Holden and Stalnaker, 1975b). Channel catfish was the most abundant species encountered in the Colorado and San Juan rivers in the Glen Canyon area (McDonald and Dotson, 1960). The species was not recorded from the White River near the RBOSP tract by Pettus (undated), but was recorded by Everhart and May (1973).

Channel catfish may be more abundant in the White River study area than the data indicate. A local resident indicated that channel catfish can be readily taken by hook and line during the summer. May (personal communication) reported two local fishermen caught about 12 channel catfish several miles upstream of the RBOSP study area during one day in summer, 1969. Holden and Stalnaker (1975b) indicated that "adults (channel catfish) were seldom taken with conventional collecting gear but were readily caught on hook and line."

Black bullhead, Ictalurus melas (introduced) - One black bullhead was captured in July 1975 at Station 26. The species was also reported from the general RBOSP study area by Everhart and May (1973). The species was reported in low numbers from several of the locations in the Glen Canyon area of the Colorado River (McDonald and Dotson, 1960), the Flaming Gorge area of the Green River (Vanicek et al., 1970) and the Green and Yampa rivers (Holden and Stalnaker, 1975b). The latter authors found the species common only in the slow-flowing waters of the lower Green River.

6) Family Cottidae - Mottled sculpin, Cottus bairdi (native) - The mottled sculpin was quite abundant in the study area and was taken during every sampling period. The great differences in abundance between sampling periods (Table 3-8-17) reflects variability of stream conditions and sampling efficiency rather than actual abundance.

This species appears infrequently or not at all in the records of studies done on the mainstream Colorado River and larger tributaries (Holden and Stalnaker, 1975a and b, Vanicek et al., 1970, McDonald and Dotson, 1960). Mottled sculpin prefer cool to cold mountain streams (Beckman, 1952; Miller, 1964). The

abundance of mottled sculpin in the study area points to the "cold water" characteristics of the stream. (The mixture of cold and warmwater species encountered in the study area may justify the classification of the White River in the study area as "intermediate" between cold and warmwater habitat.)

7) Hybrids - Only one hybrid form has been captured to date, the flannelmouth sucker X bluehead sucker hybrid (*Catostomus latipinnis* X *Catostmus discobolus*). Three specimens were captured, one in April 1975 and two in September 1975. This hybrid cross was first described by Hubbs et. al. (1943) from the Virgin River System, Utah, and subsequently by Hubbs and Hubbs (1947) from the Gunnison and San Juan river systems in Colorado.

Vanicek et al. (1970) and Holden and Stalnaker (1975b) reported catostomid hybrids, but did not record the flannelmouth sucker X bluehead sucker hybrid, despite both species occurring together in abundance. Hubbs and Hubbs (1947) stated that these two species probably have a naturally low frequency of hybridization compared to some other sucker species.

8) Other species - The white sucker, reported from the White River by Pettus (undated), is of interest because it may be "moving into" the area. Only one specimen was captured in the river while 31 were captured in Piceance Creek by Pettus. The species was first introduced into the Colorado River in about 1926 (Hubbs et al., 1943), and has spread rapidly. Holden and Stalnaker (1975b) found the white sucker to be abundant in the upper Yampa River and rare in the lower Yampa, upper Green and Colorado rivers. The species is yet to be encountered in the present RBOSP baseline study.

b. Relative Abundance and Distribution - To gain some insight into the relative abundance and distribution of fishes from the RBOSP studies, analyses of mean numbers, mean weight, and mean number of species captured to date were made for each station (Figures 3-8-26, 3-8-27 and 3-8-28). Relative abundance and distribution are discussed below by "geographical" areas, i.e., White River above Yellow Creek, confluence of Yellow Creek with White River, and White River below Yellow Creek. The grouping is not based on habitat, as

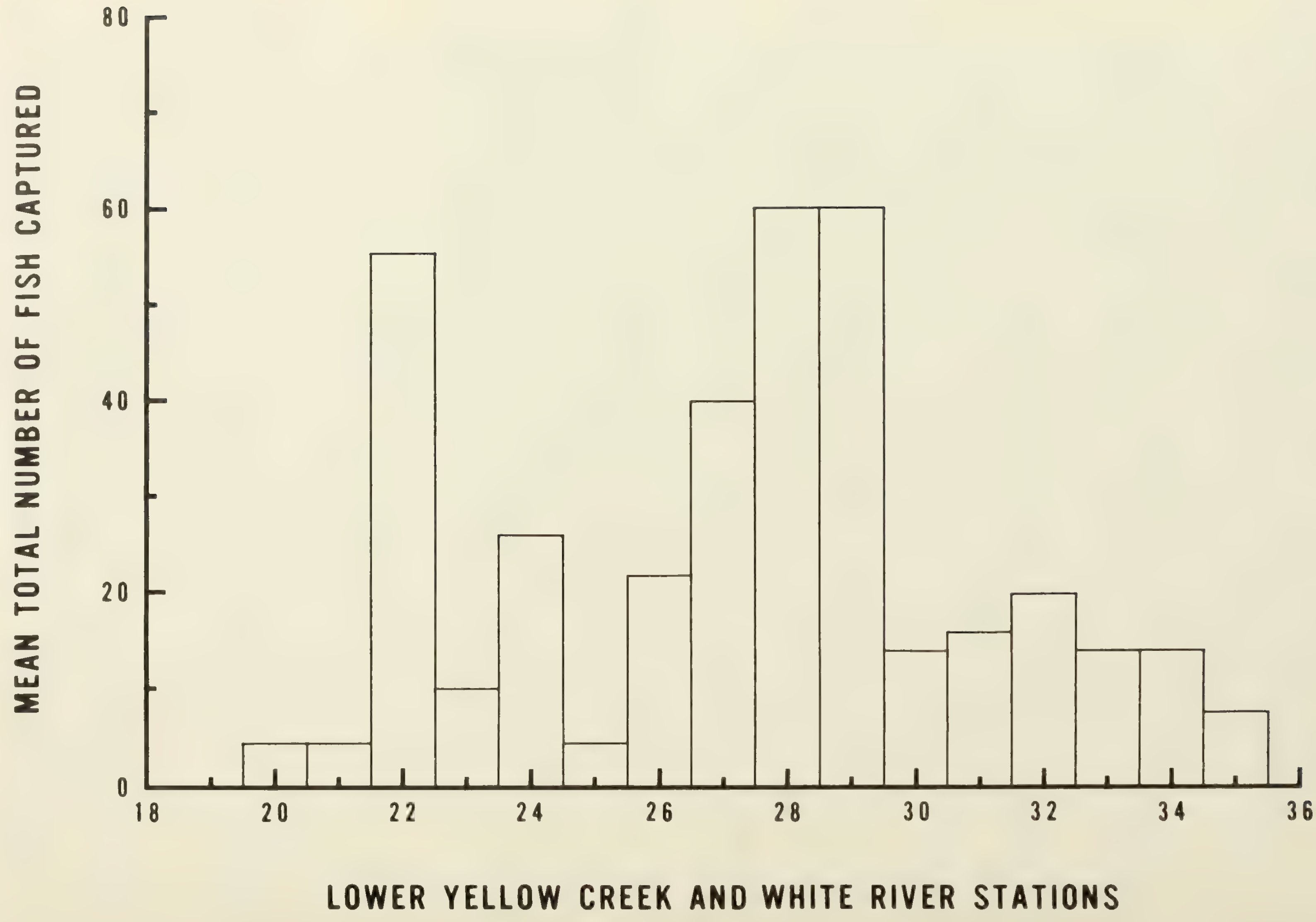

Figure 3-8-26. Mean total number of fish captured for five sampling periods during RBOSP Aquatic Baseline Studies from October 1974 to September 1975.

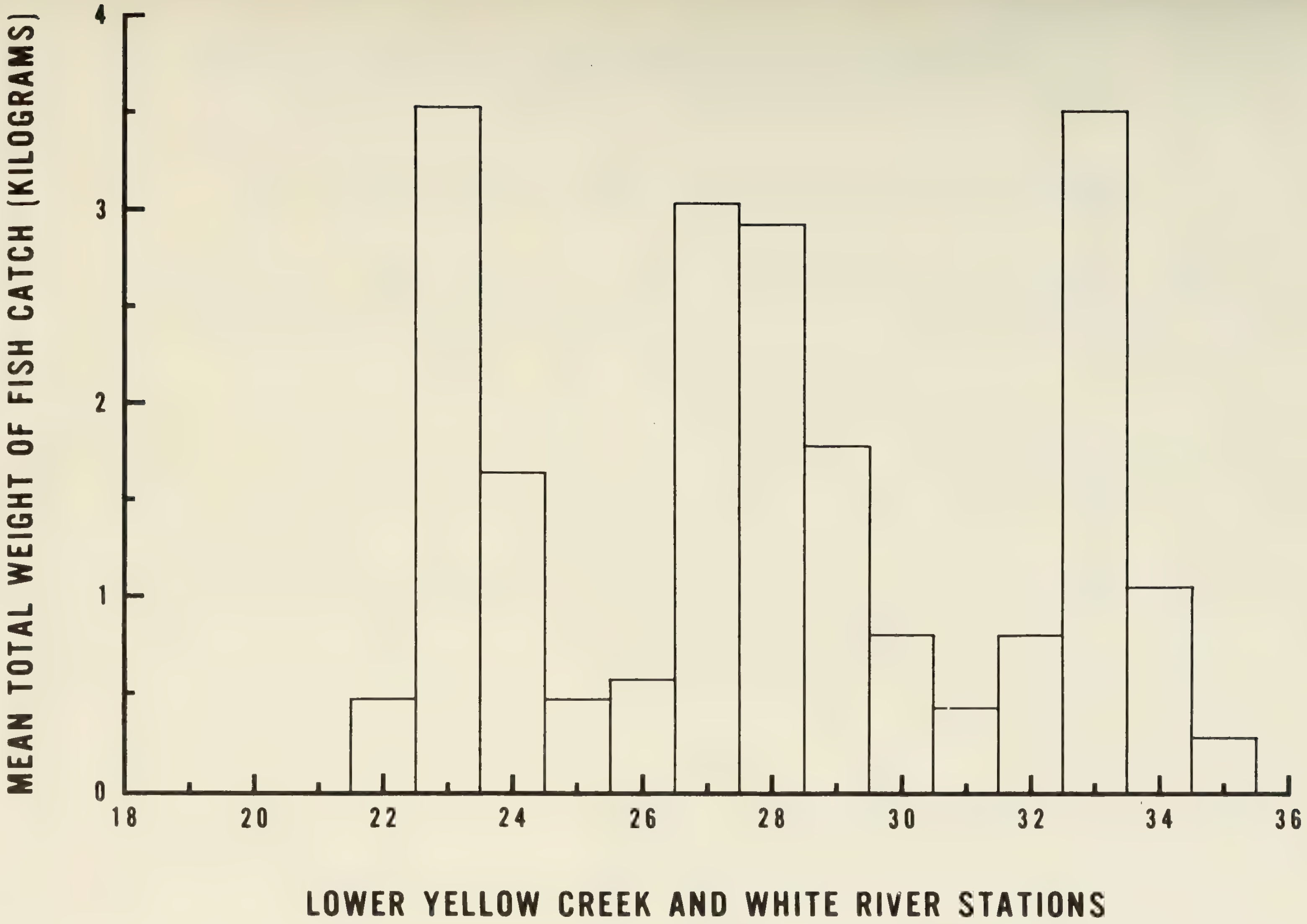

Figure 3-8-27. Mean total catch weights for five sampling periods during RBOSP Aquatic Baseline Studies from October 1974 to September 1975.

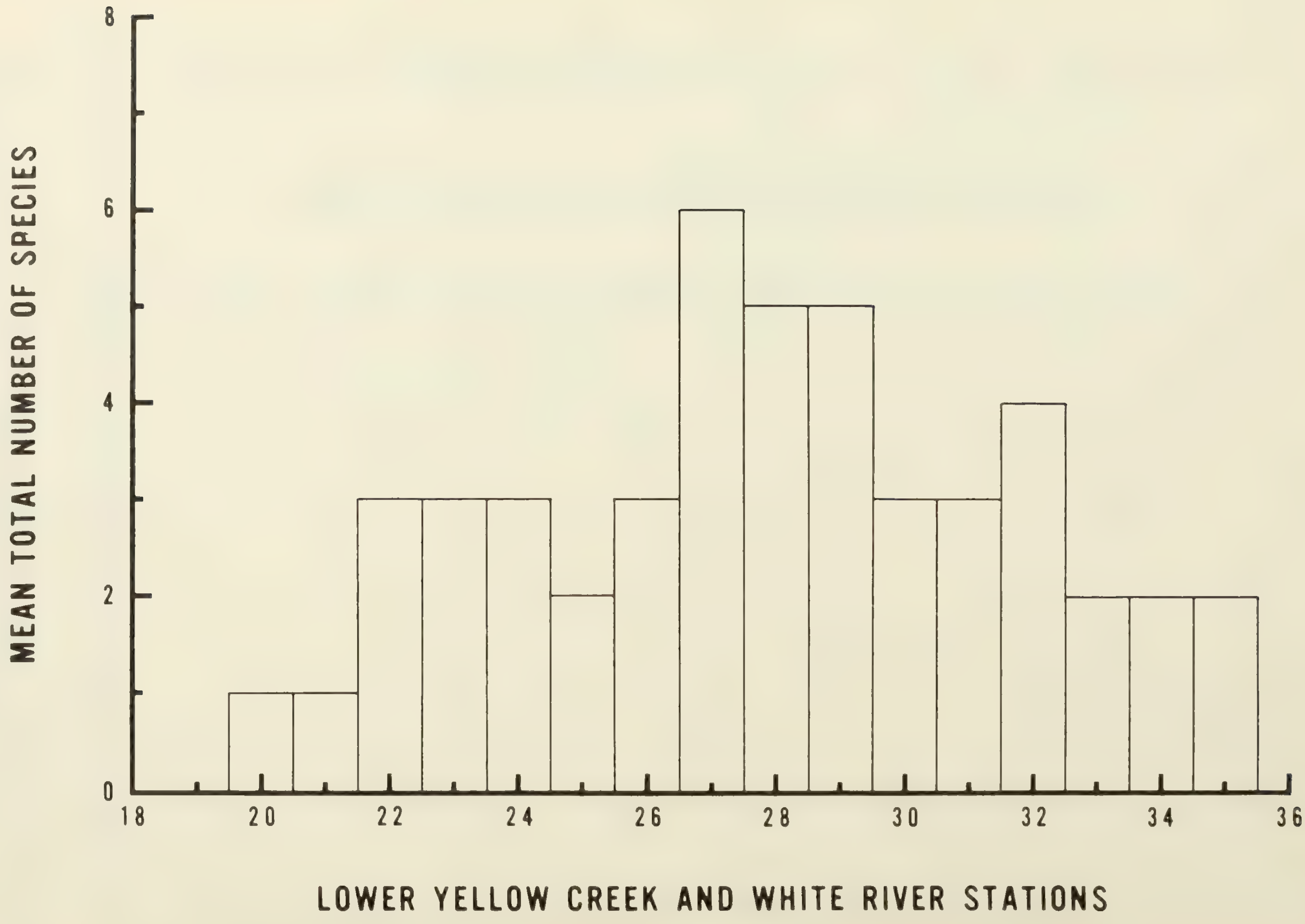

Figure 3-8-28. Mean total number of fish species captured for five sampling periods during RBOSP Aquatic Baseline Studies from October 1974 to September 1975.

various habitats, e.g., riffle, pool, exist in each area. However, the grouping is pertinent to the baseline and monitoring aspects of the program because each area has the potential of being affected differently by any environmental perturbation, with the White River above Yellow Creek being the control area.

1) Yellow Creek (Stations 20 - 22) - The catch at Yellow Creek Stations 20, 21 and 22 was low in numbers, weight, and species. This reflects the small amount of habitat available in Yellow Creek. Yellow Creek is a stream which becomes essentially a series of isolated warm water pools during much of the year. Station 22, near the mouth of Yellow Creek, is clearly different in all respects from the other Yellow Creek stations. At that station, a substantial increase in weight and species, and especially numbers is evident. What is not shown on the polygons, however, is that the major difference between Station 22 and the other stations is the result of one sampling in June 1975. The sampling occurred during spring runoff when water was backed up into Yellow Creek through the length of Station 22. The catch included roundtail chub, speckled dace, fathead minnow, carp, flannelmouth and bluehead suckers. The spring runoff period is apparently the only time Yellow Creek is used by fishes and the catch at other times was very low.

2) White River above Yellow Creek (Stations 23 - 27) - This section produced a variety of catch results, primarily because of the variable habitat encountered and sampling efficiencies. Compared to other stations, Station 23 was roughly median in numbers and species captured, but had the highest mean weight of catch. This reflects a preponderance of larger fishes (mostly suckers) captured at this station, due to the pool-type habitat and the increased sampling efficiency gained by blocking off this section with nets. Stations 24 - 26 represent a main-channel transect. Although not affected by back channels or block netting, the catch from this area still shows the influence of both habitat and sampling efficiency. Station 25 contains both shallow riffle and pool habitat and this is probably the cause of the greater numbers and weight captured relative to Stations 25 and 26. Station 27 produced greater catches in numbers, weight, and species than the other stations

in this group. The obvious reason is that it is in a back-channel, mostly pool habitat, and is usually effectively blocked off during sampling.

3) Yellow Creek confluence with White River (Stations 28 - 29) - This area produced the greatest catch of the study area in terms of numbers, number of species, and mean weight of fish. These results are apparently due to a variety of habitats available in this back channel, e.g., deep riffle, pool, undercut banks and the greater sampling efficiency due to blocking nets.

4) White River below Yellow Creek - The catches from this area were low in terms of numbers and species. However, Station 33, the only back channel, primarily pool station in the group, produced one of the highest catch weights of all stations, composed mostly of relatively large suckers.

The obvious influence of habitat type and sampling efficiency on sampling results requires discussion of the results from a different perspective than station grouping. Stations 23, 27, 28, 29 and 30 are all similar in that they are located in back channels, can be blocked off during most sampling periods, and contain all or partial pool habitat. Considering these stations as a unit, the agreement in weight (Figure 3-8-27) is very close. Station 29 is somewhat lower than the others, but has more riffle habitat, thus precluding the occurrence of great numbers of larger fish. On the other hand, the open-water stations (impossible to block off), which consist mostly of riffle habitat (Stations 24, 25, 26, 30, 31, 32, 34 and 35) were generally much lower in numbers and weight of fishes captured.

c. Age and Growth

1) Flannelmouth sucker - Data for length-frequency and scale analysis are given for the flannelmouth sucker in the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976). However, the data must be interpreted with caution because: 1) insufficient samples were collected for some age classes; 2) scales proved very difficult to read, particularly from older age

groups; and 3) no previous study has validated the scale method for the flannelmouth sucker. Because of these problems, only data on smaller fish (<314 mm) are presented, which presumably affords greater scale-reading accuracy.

Only age class I fish were detected by length frequency analysis of June 1975 samples. These fish grew to an average of 55 to 59 mm in approximately 1 yr of life. The length range and particularly the modal length for age class I fish determined by scale analysis are very similar to the length frequency derived range and mode. This is of little value in corroborating annuli (yr marks) on scales because most age class I fish in June had not yet formed an annulus on their scales.

Length frequency analysis of September samples revealed 2 age classes, 0 and I. The age class 0 fish grew to a modal length of 40 - 43 mm (1.6 inches) since hatching earlier in the year. The grouping representing age class I fish is not as distinct as that representing age class 0 fish, but the age class I mode (96 - 99 mm (3.8 inches)) appears corroborated as an age class mode by the similar mode and range for September age class I fish aged by scale analysis. The agreement between length frequency and scale data for age class I gives some support for the use of flannelmouth sucker scales; each scale in the age class I group had one annulus. Most of the scales from this same age class in June had no annuli.

The difference in modal lengths between age class I fish in June and September indicates additional average growth of 37 mm (1.5 inches) during the 3 mo period. It thus appears, at least from the present sample, that flannelmouth suckers grow to around 100 mm (3.9 inches) by the end of their second growing season.

Only one published reference, McDonald and Dotson (1960), on age and growth of the flannelmouth sucker has been found. These authors reported ages of 12 specimens from the Glen Canyon area of the Colorado River. The specimens ranged in age from 1 to 6 yr old for a 105 to 363 mm (4.1 to 14.3 inches) size range. Either the scale method or opercle bone method (annuli appear on all

hard parts of fish) was used in the study of McDonald and Dotson (1960). No information was given of criteria used to identify annuli.

A study is presently being carried out at Utah State University by Dr. Richard Wydoski on the life history of the flannelmouth sucker (Wydoski, personal communication). These investigators have encountered the same problems in aging flannelmouth sucker as encountered in the RBOSP study. They have several investigations underway to establish whether flannelmouth sucker scales are valid indicators of age. The information derived from these studies may be useful in resolving the problems of studying age and growth of the flannelmouth sucker.

2) Mottled sculpin - Some insight into age structure and growth rates of mottled sculpin was gained through length-frequency analysis of October 1974 and September 1975 samples. The data are presented in Figures 3-8-31 and 3-8-32 in the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976). In the October 1974 sample, only age class I fish could be determined. These fish had a length mode of 60 - 61 mm (2 - 4 inches). Clear-cut length modes for age classes greater than I could not be discerned because they were captured near the end of their second growing season.

In the September sample, age class 0 fish had a modal length of 34 - 35 mm (1.4 inches). A second length mode was determined at 76 - 77 mm (3.0 inches) and may represent age class I fish, although this is considerably larger than the modal length of age class I fish in the October sample. Age class 0 fish were poorly represented in the catches; only 15 specimens were captured in September 1975 and none in October 1974. This was due to reduced sampling efficiency with this class.

The growth rates of early age classes of mottled sculpin at the RBOSP site are similar to those determined in the West Gallatin River, Montana, specimens (Bailey, 1952). The modal length of age class I fish taken in the West Gallatin River in October was 61.5 mm (2.4 inches). The corresponding mode for fish captured during October - November 1974 in the present study was 60 - 61 mm (2.4 inches). The data on age class II and older fish are inconclusive in

both the Montana and present studies. Too few age class 0 fish were captured in the present study to provide useful analysis.

The largest mottled sculpin captured in the RBOSP area to date was 116 mm (4.6 inches). Bailey (1952) reported a 140 mm (5.5 inches) specimen from the West Gallatin River System. A 142 mm (5.6 inches) specimen was captured in the Green River by McDonald and Dotson (1960).

3) Speckled dace - A length-frequency analysis was conducted on speckled dace captured in September 1975. The data are presented in the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976). At least two, and possibly three, age classes were determined. Age class 0 fish exhibited a modal length of 36 - 37 mm (1.4 inches). The length mode for age class I fish was 66 - 67 mm (2.6 inches). A length mode of 86 - 87 mm (3.4 inches) may represent age class II fish; however, the reliability of this mode may not be as good as the other two. Although one other study (Jhringran, 1948 in Carlander, 1969) indicated that speckled dace live to at least age class III, such other fish if present in the White River, were too few in number to be pinpointed through length-frequency analysis.

A comparison of length-frequency data for White River speckled dace was made with data from the Trinity River, California, speckled dace (Jhringran, 1948). Dace from the Trinity River exhibited a modal length of 31 mm (1.2 inches); White River specimens had a modal length of 36 to 37 mm (1.4 inches). Age class I dace in the Trinity River ranged from 36 to 45 mm (1.4 to 1.8 inches) and age class II from 49 to 58 mm (1.9 to 2.3 inches). These values are considerably smaller than the corresponding values for White River dace. However, Carlander (1969) gives no capture dates for Trinity River fish past age class 0, making comparison difficult. Whatever the sampling dates, since the White River age class I modal length (66 to 67 mm (2.6 inches) well exceeds the length range of Trinity River age class II fish, the White River population has a much better growth rate.

There is some confusion in the literature concerning the maximum total length attained by the speckled dace. Miller (1964), Scott and Crossman (1973) and Koster (1957) reported the maximum length as 76 mm (3.0 inches). Jhringran (1948) (cited in Carlander, 1969) reported a maximum length of 88 mm (3.5 inches) in the Trinity River, California. However, speckled dace of at least 100 mm (3.9 inches) have been observed in Colorado by Behnke (personal communication). McDonald and Dotson (1960) reported a number of specimens from the Flaming Gorge area of the Green River in excess of 100 mm (3.9 inches) and one measuring 121 mm (4.8 inches). In the present RBOSP study, numerous specimens over 90 mm (3.5 inches) and seven over 100 mm (3.9 inches) including one at 109 mm (4.3 inches) have been captured.

The reason for the discrepancy in reported maximum lengths of speckled dace is most probably linked to the wide morphological variability reported for this species. Minckley (1973), citing Miller and Miller (1948), indicated that it was one of the most variable species in western North America. Scott and Crossman (1973) stated that variability was so great that it seems likely that more than one species may be involved in the taxon, *Rhinichthys osculus*.

4) Mountain whitefish - Although few mountain whitefish were captured, scale analysis results are reported here because of the potential importance of this species as a sport fish. The results of analysis of six specimens captured in September are: mean length 121 mm (4.8 inches), range 118 to 124 mm (4.6 to 4.9 inches), age class 0. These fish were larger than same age fish reported by Brown (1952) for the Gallatin River, Montana (95 mm, 3.7 inches), or one year old fish reported by Sigler and Miller (1963) for the Logan River, Utah (117 mm, 4.6 inches) and Pettit and Wallace (1975) for the North Fork Clearwater River, Idaho (113 to 115 mm, 4.4 to 4.5 inches).

The small sample size precludes confident estimates of growth rates for the mountain whitefish population in the White River. This may be possible if subsequent sampling produces greater numbers of mountain whitefish.

d. Condition Factors - Condition factors (K) have been frequently used to describe the "plumpness" or "well-being" of fish (Carlander, 1969). The principle value of such factors lies in comparing site specific condition factors with published values for the same species in other waters, i.e., comparing the present population with the "average" for the species to determine relative "well-being" and establishing a baseline with which to detect possible further environmental perturbation.

Condition factors for five relatively abundant fish species at the RBOSP site are presented in the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976).

The mean K value for all flannelmouth suckers taken to date in the RBOSP studies is 0.87. This is essentially the same as the value of 0.84 calculated from the data of Dotson (1960) and McDonald and Dotson (1960) for flannelmouth suckers from the Flaming Gorge area of the Green River. No significant change in K values were observed with increasing size of the Green River flannelmouth suckers. The same appears true of the RBOSP flannelmouth. McDonald and Dotson (1960) suggested that the homogeneity of K values for flannelmouth resulted from low intraspecific competition due to a herbivorous feeding habit; data from the present RBOSP studies suggest that this may not be the case (see section 8.F.4d, Food habits).

Little information concerning condition factors exists in the literature for the other species. K values were calculated from a small amount of length-weight data on speckled dace from Jhringran (1948) (cited in Carlander, 1969). The mean calculated K value, 0.56, is almost 50% lower than the 1.04 value calculated for the RBOSP speckled dace; however, the great inter-population variability of the speckled dace could be responsible for much of this difference.

As stated previously, one important aspect of condition factors is their utility in monitoring environmental perturbations or pollution. The present year's data, when supplemented by an additional year of data, should

provide a good baseline for monitoring any subsequent changes in condition.

e. Food Habits

1) Flannelmouth sucker - Major emphasis was placed upon the food habits of the flannelmouth sucker. These data are presented in the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976).

Immature aquatic insects, primarily midges (Chironomidae) and mayflies (Ephemeroptera) and, to a lesser extent, black flies (Simuliidae), caddisflies (Trichoptera) and other insects comprised the major portion of the diet of the flannelmouth sucker. Some differences in relative abundance of major food items were observed with season. The frequency of occurrence of both Ephemeroptera and Chironomidae was lower in June and July 1975, with a slight increase in September 1975. These groups also occurred in reduced numbers in the benthos samples in June and July and in slightly increased numbers in September. The occurrence of these organisms in flannelmouth sucker stomachs appears related to their availability in the environment. In general, the Chironomidae and Ephemeroptera metamorphose into the adult form and emerge from the water in the spring and early summer, thus greatly reducing their availability as fish forage.

In evaluating the contributions of the various insect groups to the fish diet, care must be taken in assigning "importance" to certain groups. The Chironomidae were consistently found in the greatest number of stomachs and in the greatest abundance. However, the large number of individual Chironomidae present is deceptive because of the relatively small size of these organisms. For example, in April 1975, chironomids constituted 63% of the total food items in all stomachs. The stoneflies (Plecoptera), mayflies (Ephemeroptera) and caddisflies (Trichoptera) together constituted 35% and occurred in a high percentage of stomachs. The greater relative size of the latter organisms (at least tenfold and up to 100-fold in some cases) indicates that the greater portion of the diet, in terms of biomass or caloric intake, was made up of immature

stoneflies, mayflies and caddisflies. The same condition existed in June, July and September, but to a lesser degree. The low frequency of occurrence of mayflies and caddisflies in June, July and September suggests that Chironomidae and other items were relatively more important (biomass) in these months than in April.

Plant material and algae occurred in significant numbers of stomachs in June and July. Plant material consisted of seeds and pieces of higher plant tissue, often clearly terrestrial in origin. Algae were filamentous. One reason for this has to be availability -- filamentous algae were more abundant during the latter half of the summer and early fall (see section 8.2C, Periphyton). Also, plants of terrestrial origin would presumably be more available at this time because of hay cutting operations that took place in fields adjacent to the river several times during the summer. The increased consumption of plant material and algae may also have been related to the reduced availability of insects at this time. The increased consumption of plant material by bluegill (Lepomis macrochirus) during periods of reduced insect availability has been reported by several investigators (Scott and Crossman, 1973). This may be the case with the flannelmouth sucker since plant consumption decreased in September when insects showed an increase, while algae and, presumably, other plant material were still abundant.

The results of the food habit analysis of the flannelmouth sucker is especially significant in light of what has been reported in the literature. Since Jordan (1891) reported that the stomach of one specimen contained filamentous algae and other vegetation, the species has been considered herbivorous. Ellis (1914) cited the earlier opinion of Jordan and Evermann (1896) and also presented stomach data for nine specimens from the Grand and Uncompahgre Rivers in western Colorado. Seven of these specimens contained plant material of some type: algae, higher plant fragments or seeds. Two specimens contained only "slime". McDonald and Dotson (1960) reported that the stomachs of four flannelmouth suckers taken from the Colorado River in Utah contained algae and unidentifiable material. Later authors, apparently relying on these earlier reports, listed the flannelmouth sucker as completely or largely herbivorous

(Koster, 1957; Sigler and Miller, 1963; Carlander, 1969; Everhart and Seaman, 1971). The only dissenting opinion has been that of Minckley (1973) who stated in his book, "Fishes of Arizona", that the flannelmouth sucker "feeds extensively on bottom invertebrates" in the Salt River, but presented no stomach analysis data.

Although it is difficult to extrapolate food habits from one area to another, it appears that, with the data from the present food habit analyses of flannelmouth suckers, and Minckley's (1973) notation, the classification of this species as herbivorous is in error. It appears that the herbivorous classification was derived from examination of only 14 specimens (Jordan, 1891; Ellis, 1914; and McDonald and Dotson, 1960). At least 13 of these 14 specimens were captured in July and August, a time when the White River specimens (present study) ingested significantly more plant material. It is not surprising, due to the small number of specimens previously examined and the time of the year when they were captured, that the literature reports the flannelmouth sucker as an herbivore.

2) Mottled sculpin - Mottled sculpin fed primarily on mayflies, caddisflies and stoneflies: Hydropsychidae (Trichoptera) were dominant in October 1974, Ephemeroptera in April and June 1975, and Hydropsychidae in September 1975. No clear trends were shown in July because of the small number of specimens examined. Although seasonal trends were evident, the causes were difficult to establish. Stoneflies (Plecoptera), primarily the genus *Isoperla*, were significant in the diet only in April. This taxon also showed the same pattern of abundance in the benthos samples (see Section 8.2D, Benthos). Also, the largest instars of this taxon were available in April, and were presumably more vulnerable to predation by sculpins. Hydropsychidae were presumably more vulnerable to predation by sculpins. Hydropsychidae were abundant in the stomachs in October 1974 and September 1975 and lower in the summer. This generally corresponds to their abundance in the environment. However, hydropsychids were quite low in April stomachs, at a time when there appeared to be reasonable numbers in the environment. This may have been due to sculpins actively selecting mayflies and stoneflies. Dunlevy (unpublished

manuscript) showed that mottled sculpins exhibit some degree of selectivity in feeding. Also, the preponderance of mayflies in the stomachs of nine of ten fish taken in June suggests selective feeding because the abundance of mayflies in the river had decreased greatly from April to June 1975.

Fish remains were found in the stomachs of one mottled sculpin in October 1974 and ten fish in September 1975. Fish generally constituted only a small part of the diet of mottled sculpins as a group. Bailey (1952) reported fish remains in only five of 768 sculpins from the West Gallatin River, Montana. Fish were relatively more important in the diet of White River mottled sculpins at least in September 1975, with 10 of 81 specimens containing fish remains. Only the larger sculpins consumed fish in both studies (fish greater than 66 mm (2.6 inches) and 80 mm (3.2 inches) in the White River and West Gallatin River, respectively). The mean length of the ten White River specimens was 89 mm (3.5 inches).

The general benthic feeding habits of the mottled sculpin agree with the findings of earlier investigators as reviewed by Bailey (1952) and Scott and Crossman (1973). However, sculpins in the West Gallatin River (Bailey, 1952) relied more on chironomids and less on ephemeropterans than those in the White River (present RBOSP study). Although relative numbers of chironomids consumed by West Gallatin River sculpins was greater, the great size differential of Ephemeroptera and Trichoptera versus Chrionomidae suggests that the former constituted the bulk of the nutritional material ingested.

3) Bluehead sucker - Stomach analyses were made on a relatively few specimens. The small quantity of data obtained indicated omnivorous feeding habits for this species, since both plant and animal material was found in stomachs of this species. The amount of vegetable material consumed may not be adequately expressed in the data, however. Examination of the stomachs of the six specimens collected in April 1975 revealed no insects or other animal material. The stomach contents (in several cases, the stomachs were nearly full) were then processed, mounted on glass slides and examined under high magnification. This examination revealed large numbers of diatoms, primarily

Navicula viridula. This species was also dominant in the river at that time.

Although giving no stomach analysis data, Smith (1966) stated that the long, coiled intestine and cartilaginous scraping edge of the lower lip suggest herbivorous feeding habits for the bluehead sucker.

4) Other Species - Stomach analyses data for roundtail chub, carp, mountain whitefish, rainbow and brown trout are presented in the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976). Little interpretation can be made because of the limited numbers of specimens examined. The results appear to follow what has previously been established for these species; that is, mountain whitefish and carp are benthic feeders, the trout are both benthic and surface feeders, and roundtail chubs take benthic, drifting and swimming organisms--including fish.

f. Reproduction - Some insight into the reproductive status of fishes was made through observation of gonad condition and presence of young-of-year fishes. Because of the existence of more data on flannelmouth suckers, only this species is discussed individually.

1) Flannelmouth sucker - Examination of the gonads of flannelmouth suckers revealed that the fish did not attain sexual maturity until they had grown to around 400 mm (16 inches) in length. Although sex could be determined in the field on some specimens over 300 mm (12 inches), most of these had obviously underdeveloped gonads. In April 1975, eight mature males were captured that ranged from 351 mm to 474 mm (12.2 to 18.7 inches) in length (mean = 421 mm or 16.6 inches). Nine mature females averaged 433 mm (17.4 inches) and ranged from 413 mm to 480 mm (16.3 to 18.9 inches). One possible (underdeveloped) male was recorded at 403 mm (15.9 inches) and three obvious (but quite undeveloped) females at 368, 382 and 406 mm (14.5, 15.0 and 16.0 inches), respectively. That spawning of flannelmouth suckers took place between the April and May - June 1975 samplings was suggested by the obviously spent condition of mature fish captured during June. Four females, 422 to

472 mm (16.6 to 18.6 inches) and five females, 345 to 364 mm (13.6 to 14.3 inches) were recorded as either spent or immature (condition could not be determined). Two males at 423 and 429 mm (16.7 and 16.9 inches), although largely spent, still released some milt with pressure.

Although relatively few specimens were examined, it appears probable that spawning of the flannelmouth sucker takes place sometime during May and June, and probably largely in June (as indicated by the condition of the gonads). The temperature at which spawning takes place appears to be around 12 - 13^{0}C, the temperature recorded for the White River in both April and June 1975. There is apparently no published information on the spawning time or temperature for the flannelmouth sucker.

2) Young-of-year fish - The presence of young-of-year fish in late season is the first indication of successful reproduction in a given year. Although relatively large numbers of adults generally indicate successful reproduction, a given year's success can only be measured by the recruitment of young-of-year fish late in the season. A significant number of young-of-year fish, primarily flannelmouth, bluehead suckers and speckled dace appeared in the study area in September 1975. These fish were captured mostly in nearshore, quiet-water areas and in back channel habitats. Also, many young-of-year suckers and dace were observed in cutoff pools and channels that were part of the normal sampling stations.

In summary, fish were found only in the White River and, to some extent, in Yellow Creek. In the present study area, the fishery habitat of the White River appeared to be intermediate between cold and warm water habitats, as suggested by the mixture of cold and warm water species observed there. The high water temperatures which have occurred periodically and the high turbidities which occurred in these waters undoubtedly restricted the occurrence and abundance of trout species. The fishery of this area of the White River was thus dominated by rough and forage species. A total of 15 fish species and one hybrid form was observed in the White River and Yellow Creek during RBOSP aquatic studies. The most common species were flannelmouth suckers,

bluehead sucker, speckled dace, fathead minnow, and mottled sculpin. The fish existing at the site comprise a mixture of consumer groups, although most were secondary consumers. Food habit studies of the most abundant fish species in the area indicate that benthic invertebrates belonging to the Chironomidae, Plecoptera, Ephemeroptera, and Trichoptera comprised the major portion of the diet of those species. The relative importance of specific macroinvertebrate groups in the fish diet varied somewhat according to season and with the abundance of the invertebrates.

In general, few fish were observed in Yellow Creek. The brackish nature of Yellow Creek, particularly the high concentrations of sodium and chloride along with the limited habitat available and periodic high temperatures, generally restricted the occurrence of fish. However, during the period of maximum flow in the White River, a large backwater area was created near the mouth of Yellow Creek and a considerable increase in the number of species and individuals was observed.

Because of the importance of fish as consumers in the White River aquatic ecosystem and because of the usefulness of such measurements as fish condition factors in following trends in aquatic ecosystems, fish studies would serve to indicate trends at the primary, secondary, and tertiary consumer levels during the monitoring phase.

5. Threatened and endangered species

No rare or endangered fishes were encountered during the present RBOSP baseline study. However, two species that are considered rare or endangered, bonytail and Colorado squawfish, were previously captured near the present study area by Everhart and May (1973).

The bonytail is very rare throughout the Colorado River Basin (Holden and Stalnaker, 1975b). Everhart and May (1973) reported the bonytail in the White River during 1969. Seaman (1962) indicated that bonytail occurred 50 miles upstream in the White River from the Colorado state line, a distance that would include the RBOSP study area. However, it is not clear what species Seaman was referring to since prior to 1970, the name "bonytail" was often used to refer to both forms now known as *Gila robusta* and *Gila elegans*, (e.g., Eddy, 1957; Sigler and Miller, 1963; Smith, 1960). Behnke (unpublished manuscript) indicated that the status of the bonytail in the White River was unknown, but that it may be declining as in the Yampa and Green Rivers.

Everhart and May (1973) also recorded Colorado squawfish near the RBOSP study area. This species is listed as "endangered" by the U.S. Department of the Interior (1974). This species has been drastically reduced in abundance in the Colorado River Basin, apparently due to dam construction. One of the last significant populations of this species, in the Green and Yampa rivers, is experiencing poor reproductive success, and may be in decline. Behnke (unpublished manuscript) indicated that the Colorado squawfish is "evidently rare or virtually gone" from the White River. May (personal communication) indicated that the Colorado squawfish captured in the White River during 1969 (Everhart and May, 1973) were few in number and were encountered upstream from the RBOSP study area.

8.3 STATISTICS

A. Confidence Limits - for the RBOSP Aquatic Sampling Program confidence limits to means of selected chemical and biological parameters were calculated for certain geographic locations for each sampling date. These limits are the upper and lower boundaries of the confidence interval of the mean and imply that the probability of the interval covering the mean is 0.95.

In constructing the confidence limit for RBOSP Aquatic Program, an analysis of variance table was constructed. For this table the error mean square for testing the interaction between the sampling dates and geographic regions within geographic regions was determined. This analysis was not used for testing purposes. It does, however, provide an estimate of this latter mean square to use in calculating the standard errors for the confidence limits for each geographic region by sampling date. These standard errors were then multiplied by the appropriate t-value and the upper and lower boundaries for the confidence interval were determined.

The method used in calculating the confidence limits was to group the sampling locations for each of the six (6) sampling dates and then to perform an analysis of variance on the selected parameters. The calculated mean squares from these analyses were used in constructing the limits.

The sampling locations were grouped as follows:

Region	Sampling Location
1	1 - 5
2	6 - 18
3	18 - 22
4	23 - 27
5	28 - 29
6	30 - 35

With the above sampling locations defining six (6) regions, the following analysis of variance was performed:

Source of Variation	Mean Square
Region	MSR
Date (Region)	MSS (R)
Date	MSD
Date * Region	MSDR
Date * Site (Region)	MSDS (R)
Error	MSE
Total	

The MSDS (R) mean square was used as the variance of the mean for each data by region mean, and thus, all standard errors for each parameter were constructed using this mean square. This is,

$$\text{Standard Error} = \sqrt{\frac{\text{MSDS (R)}}{n}}$$

where n is the number of observations for each mean.

To calculate the upper and lower limits for the confidence interval, the standard error of the mean was multiplied by the appropriate t-value. All t-values were determined at the 0.05 level of significance and are as follows:

Data Type	Degrees of Freedom	t-value
Phytoplankton	99	1.984
Periphyton	99	1.984
Zooplankton	101	1.983
Benthos	69	1.995
Water Chemistry	103	1.983
Sediment Chemistry	103	1.983

Thus, the limits were calculated as

(LL, UL)

where LL = lower confidence limits = $x - t(0.05, df)$ SE

UL = upper confidence limits = $x + t(0.05, df)$ SE

$t(0.05, df)$ = t-value at 0.05 level of significance with df degrees of freedom

SE = Standard Error of Mean

For the RBOSP fish program, confidence limits to means of selected fish parameters were calculated. These limits are the upper and lower boundaries of the confidence interval of the mean and imply that the probability of the interval covering the mean is 0.95. The method used in calculating standard errors and thus confidence limits for the fish catch data was to calculate the variance of the parameters for the combined effort. This term was then used in calculating the standard errors and thus the confidence intervals for each parameter. This is,

$$\text{Standard Error} = \sqrt{\frac{\text{variance}}{n}}$$

$$\text{variance} = \frac{1}{n-1}\left[\sum_{i=1}^{n} x_i^2 - n(\bar{x})^2\right]$$

To calculate the upper and lower limits of the confidence interval, the standard error of the mean was multiplied by a t-value. All t-values were determined at the 0.05 level of significance, and are as follows:

Stations	Degree of Freedom	t-value
20 - 24, 26 - 30, 32 - 35	4	2.776
25 and 31	3	3.182

Confidence limits for the parameters discussed above are presented in Section 8.3 of the Environmental Baseline Studies, Annual Report for 1975 (RBOSP, 1976). In this report observational data have been presented for certain parameters (e.g., aquatic macrophytes) where confidence intervals have not been generated. In those cases, the data are important in describing the existing aquatic habitats.

B. Diversity Indices - Diversity indices are a measure of the variability for the information of a species.

1. Shannon Index:

The formula for the Shannon index is:

$$H' = -\Sigma p_i \log p_i$$

where $p_i = N_i/N$

N_i = amount of information for the i^{th} species.

N = amount of information for the whole sample.

This index was proposed by Shannon as a measure of the information content of code. However, ecologists currently are using it as a measure of a community's diversity.

2. Shannon Evenness Index:

The formula for this index is:

$$J' = H'/H' \max$$

where H' = Shannon Index

$H' \max = \log s$, s = total number of species in the sampled community. The evenness index is a measure of how well the individuals are apportioned among the species and it is the ratio of the observed diveristy index to the maximum value the index could have in a community with the same number of species.

3. Richness

The formula for this index is:

$$d = (S-1)/\log N$$

where S = total number of species in the sampled community

N = total number of individuals in the sampled community.

This index is a measure of species richness component of diveristy, and weights species number more than total abundance (N).

Shannon functions serve well in biological analyses because they are robust and their distributions are well known.

C. <u>Statistical Data</u> - Confidence limits to means of chemical parameters and for periphyton, phytoplankton, zooplankton, benthos, fish, and sediment

chemistry are presented in Section 8.3 of the Environmental Baseline Studies Annual Report for 1975 (RBOSP, 1976).

8.4 AQUATIC INTERRELATIONSHIPS

The plant and animal associations found in a body of water are largely determined by geography and history. In a more restricted sense, they are a function of the sum of environmental conditions affecting them. Such conditions include not only the physical and chemical characteristics of the surroundings, but also the biological conditions. The intent of this section is to relate, in a general way, the occurrence of aquatic communities to sum of environmental conditions at the RBOSP site (for more discussion see Chapter 14, Section 3).

The distribution and abundance of organisms in streams are largely determined by the physical and chemical characteristics of the aquatic system. Two of the most important factors in determining the distribution and abundance of organisms in streams are the velocity of the current and the nature of the bottom substrates (which are closely related). A third factor which is of great significance to the biology of the streams of semi-arid regions is the permanency of flow. Intermittent streams are inhabited by specially adapted fauna.

The physical nature of aquatic habitats included in the RBOSP Aquatic Baseline Studies range from small, shallow spring-brooks of less than 0.3 m (1 ft) in width and less than 2.5 cm (1 inch) in depth, to small shallow ponds, and to the major streams like the White River, which at times exceeded 46 m (150 ft) in width and 1.2 m (4 ft) in depth. Bottom substrates in these habitats range from silt and detritus to cobbles, and current velocities differ greatly among the various sampling areas. In addition, several of the small springbrooks in the study area are intermittent in nature.

Dissolved oxygen concentrations vary considerably among stations and seasons. All waters in the study area are very alkaline, particularly Yellow Creek. The relatively soluble substrates comprising the drainage produce high concentrations of dissolved materials.

Waters included in the RBOSP Aquatic Baseline Studies range from hard to very hard. All contain both carbonate and non-carbonate hardness. In Yellow Creek,

magnesium occurs in greater concentrations than calcium (together, these cations are generally the major contributors to carbonate hardness), a reverse of the usual situation in most waters. The concentration of dissolved solids and of the major contributors (carbonates, bicarbonates, sulfates, and chlorides) to dissolved solids were relatively high in all areas, but particularly so in Yellow Creek. Suspended solids concentrations were generally highest in the waters on or near Tract C-a and lowest in the headwaters. Waters of the tract area and Yellow Creek generally carried the greatest quantities of organic carbon. Waters in the tract area also contained relatively great quantities of organic nitrogen. The higher quantities of organic matter in waters on or near the tract and in Yellow Creek are likely due to greater contributions of allochthonous organic material from nearby plant communities and grazing livestock. Inorganic plant nutrients, particularly nitrogen and phosphorus, were usually found in concentrations greater than those considered limiting for the growth of algae and were often at levels considered enriching.

Of all the aquatic habitats included in the RBOSP Aquatic Baseline Studies, Yellow Creek had the most unusual and the harshest chemical conditions. In the region of Yellow Creek nearest to its confluence with the White River, sodium concentrations approached the upper tolerance limits for freshwater fish.

In all ecosystems, the three principal kinds of organisms (decomposers, consumers, and producers), are interdependent and their relationships are trophic. In many streams and rivers the primary production which supports other trophic levels is, to a large degree, derived from sources outside the aquatic ecosystem (allochthonous). Thus, allochthonous detritus derived originally from terrestrial vegetation is of great importance to the secondary trophic level since in many systems a majority of animals at the second trophic level are detritus-feeders. In other streams, however, periphyton, or the benthic algal community, is the most important source of fixed energy and herbivores comprise a majority of the animals at the second trophic level. However, as periphyton contains detritus (allochthonous and autochthonous) mixed with algae, protozoa, etc., the distinction between herbivorous and detritivorous secondary

consumption is not easy to quantify. Thus, virtually all flowing waters have secondary trophic levels that are a combination of herbivores and detritivores, composed of benthic and planktonic invertebrates and some fish. Top trophic levels generally are composed of fish.

As noted by Cummins (1974), "the present status of our knowledge of stream ecosystem structure and function is based on a number of generalizations that have been tested to some degree primarily in woodland streams of the temperate zone." In such woodland streams a majority of the energy input (primary production) is imported from the terrestrial surroundings (allochthonous material). Because of the paucity of data concerning the role of allochthonous material in unwooded, semi-arid regions, no definitive statements can be made as to the relative importance of allochthonous material to the energy (food) supply of stream ecosystems in these regions. The waters of the present study area probably contain a considerable amount of allochthonous organic material, and this material may be an important source of energy for those ecosystems.

The major source of autochthonous primary production in the waters of the present study area is periphyton. Periphyton standing crops tended to be greatest in the White River and smallest in the waters of the headwater and tract areas. In the alkaline spring-brook habitats of the headwater and tract areas, diatoms comprise the dominant algal group in the periphyton. The most abundant taxa were *Achnanthes minutissima* and *Navicula cryptocephala*. Both of these species are considered characteristic of alkaline, periphytic habitats. In the headwaters, peak algal densities (cell densities and organic weight) occurred in December 1974 - January 1975; in the tract region, a peak in cell densities and organic weight also occurred in December 1974 - January 1975, with an additional peak in April 1975. The periphyton diversities were lowest in the headwater and the tract regions, (The annual mean Shannon diversity index was 1.85 at the headwaters and 1.87 in the waters of the tract.) suggesting that the periphyton communities in these regions are less complex than those in the more permanent streams of the region. The low diversities observed in the headwaters may be attributed to the limited habitat complexity and availability of a diverse upstream seed source.

In the alkaline spring-brook habitats of the headwater and tract regions, the phytoplankton constitutes a secondary source of autochthonous primary production. The composition and species abundance of the phytoplankton of these habitats and the phytoplankton abundance indicate that the phytoplankton is primarily recruited from the periphyton. Because of the low phytoplankton abundance in the spring-brooks and the fact that the major source of phytoplankton recruitment is the periphyton, the importance of phytoplankton in autochthonous primary production is secondary to that of the periphyton.

The zooplankton fauna occurring in the spring-brook habitats of the headwater and tract areas consists primarily of species which are associated with a substrate. The bottom substrates of these spring-brooks consist of gravel, sand, and shale often covered with periphytic algae. Macrophytes were rare or absent, and their absence may account for the low abundance of littoral Rotifera and Cladocera. The dominant Crustacea in these spring-brooks included the cyclopoid _Eucyclops agilis_ and the harpacticoid _Bryocamptus hiemalis_. The most important factor controlling the distribution of zooplankton taxa in these waters is temperature. The peak densities and number of species of rotifers and cladocerans occurred during the summer months. Maximum densities of the predaceous cyclopoids can be related to the increased abundance of their food, i.e., rotifers and cladocerans. The harpacticoid copepod _Bryocamptus hiemalis_ and the rotifer _Notholca_ were restricted to these spring-brooks during the summer but more widely distributed during winter months and were thus limited by temperature. The zooplankton fauna serves as a source of food for many benthic macroinvertebrates which are either filter feeders or predaceous. The benthic fauna of the spring-brooks of the headwaters were similar probably due to the similarity of the chemical characteristics and substrates of the streams. The Naididae and Enchytraeidae comprised the bulk of the oligochaete population in the headwaters. The aquatic insects which occur in the spring-brooks of this area have univoltine (one generation/year) or multivoltine (more than one generation/year) life cycles. Aquatic insects which require two or three years for development have not been successful in invading these headwater habitats. Dipterans, particularly the Chironomidae and Simuliidae, were the most abundant aquatic insects in the headwater region. The feeding habits of the benthic

fauna of the headwater spring-brooks range from the herbivorous Hydroptilidae (Trichoptera), which feed on periphyton to carnivorous Odonata, Plecoptera, and Chironomidae. The feeding habits of the most abundant benthic organisms are: Oligochaeta--detritus feeders; Tanypodini and Chironomini--carnivorous; Ephemeroptera--primarily herbivorous; and Simuliidae--detritus feeders.

The benthic fauna of the spring-brooks of the tract area included species with the rapid cycles and species which can easily invade new waters by various means; such as adult forms which deposit eggs, immature stages which drift downstream or actively move upstream, or by burrowing into the loose substrates (hyporheic zone) and exist in a dormant state until conditions become more suitable. Adaptations such as these enable these species to exist under the condition of intermittent flow which persists in many of the aquatic habitats of the tract area. While the densities of certain benthic taxa remained high in this region, the number of species, diversity and richness were lower than in the spring-brooks of the headwater area. (The annual mean Shannon diversity index for the headwater stations was 2.65, whereas, the annual mean Shannon index for the tract stations was 2.47.) The intermittent nature of many of these waters undoubtedly limits the fauna which can exist there and thus limits diversity. As in the headwaters, the Diptera, Ephemeroptera and Oligochaeta dominated the benthic fauna in the spring-brooks of the tract region.

In the headwater and tract regions, ponds and marshy areas composed the second type of aquatic habitat observed. Station 5 is a marshy seepage area which is flat and covered with sedges, watercress and other vegetation. Station 14 is a pond in which thick mats of aquatic macrophyte _Zannichellia palustris_ grows abundantly during the summer. Station 5 has a substrate of compacted gravel with periphyton encrusted on the gravel.

In the two ponds of the tract and headwaters, aquatic macrophytes contribute a greater portion of the autochthonous primary production than in the spring-brooks but much of this plant material is not used by primary consumers since, according to Cummins (1974), rooted aquatic macrophytes are subject to little animal feeding except at times of dieback. Periphyton is thus a major source

of autochthonous primary production in the marsh and pond areas. At Station 14, periphyton cell densities were generally higher than at the other tract stations. Nitzschia denticula, a diatom, flourished in this habitat. The chemical composition of Station 14 was also slightly different from other tract stations (sulfate, magnesium, hardness and dissolved solids concentrations were higher than at other tract stations).

Phytoplankton in the ponds of the headwater and tract areas constitutes a secondary source of autochthonous primary production. In the ponds as well as the spring-brooks of the area, low phytoplankton abundance and the fact that the major source of phytoplankton appeared to be the periphyton, emphasizes the importance of periphyton.

The zooplankton fauna of Station 5 was generally similar to that of Yellow Creek. At Station 14, the dominant taxa included rotifers and crustaceans. At Station 14, the dominance of Ceriodaphnia quadrangula and the high densities of rotifers such as bdelloids, Monostyla, Lepadella, Euchlanis and other monogononts are related to the abundance of macrophytes, as their abundance is governed by the amount of suitable substrate. The zooplankton fauna at these sites included rhizopods, other protozoans, rotifers, chydorid cladocerans, harpacticoid copepods (all herbivores) and cyclopoid copepods (predominantly carnivores). As in the spring-brooks, temperature is an important limiting factor in controlling the distribution and abundance of zooplankton in these habitats.

The benthos communities of the pond and marshy habitats differed from those of the spring-brooks. At Station 5, the increased food supply (from decaying aquatic vegetation), the substrate and higher dissolved solids concentrations contributed to the increased number of species and individuals which occurred here and not at the other headwaters. At Station 5, Tubificidae, Chironomidae, Ephemeroptera, Simuliidae, Hydroptila and Grammotaulius were abundant or common. At Station 14, the benthic community included Callibaetis, Corixidae, Dytiscidae, Chironomidae (Micropsecta), Ceratopogonidae and Anthomyiidae. The most abundant Oligochaeta included the Naididae and Enchytraeidae. The feeding habits of the dominant benthic organisms at Station 5 included: Tubificidae--detritus and

bacteria; Chironomidae--carnivores or algal-detritus; Simuliidae-algal-detritus; Hydroptila and Grammotaulius--periphytic and planktonic algae; Ephemeroptera--primarily herbivorous. At Station 14, the feeding habits of the most abundant benthic organisms included: Ephemeroptera--primarily herbivorous; Chironomidae --carnivores or algal-detritus feeders; Naididae--phytophagous; other Oligochaeta --detritus feeders.

In Yellow Creek the high levels of dissolved solids and generally harsh chemical conditions limit the types of organisms which can exist in its very hard waters. Two habitat types were observed in Yellow Creek during the RBOSP Aquatic Baseling Studies. Station 19 is a pond area usually choked with growth of the alga Chara kieneri. It generally had lower water temperatures and lower concentrations of sodium, chloride, and dissolved solids but higher concentrations of sulfate and hardness than the other Yellow Creek stations. At Station 19 the major source of autochthonous primary production is the attached alga Chara kieneri and periphytic algae. Periphyton diversity was very high at Station 19, probably because of the greater number of habitats available (epiphytic, periphytic, etc.). Periphyton diversity (annual mean Shannon index = 2.30) throughout Yellow Creek was greater than in the tract or headwater regions but less than that in the White River (annual mean Shannon index = 3.00). This is probably due to the fact that Yellow Creek has more permanent flow and a greater number of periphyton seed sources than areas of the headwaters and tract, but less suitable substrates and harsher chemical conditions than the White River. The densities of periphyton at Station 19 were similar to those at the other Yellow Creek stations (20 - 22), but the species composition was different. The most abundant species at Station 19 included the alkaliphilous diatoms Rhopalodia gibberula, Nitzschia denticula, Nitzschia frustulum, Navicula cryptocephala and Navicula sp. whereas those at the other stations were Achnanthes minutissima, Fragilaria vaucheriae, Cyclotella meneghiniana, Navicula pelliculosa, Cymbella affinis, and Calothrix spp. The greatest organic weight of periphyton at the Yellow Creek stations was found in May - June 1975, while the greatest cell densities were observed in December 1974 - January 1975. The higher organic weights which occurred in May - June 1974 were probably due to the occurrence of filamentous blue-green algae and species of larger diatoms.

As in the tract and headwater areas, in Yellow Creek the phytoplankton played a secondary role in autochthonous primary production. The differences in phytoplankton species composition and abundance was greater at Stations 20 - 22 than at Station 19. The most ubiquitous and numerous species was Cyclotella meneghiniana, a species characterized by Lowe (1974) as being periphytic, tychoplanktonic, or euplanktonic; as having an optimum pH range of 8.0 to 8.5; and as being stimulated by small amounts of salt.

The composition and abundance of zooplankton fauna also differed between Station 19 and the other Yellow Creek stations. The abundance of Chara kieneri, the lower water temperatures, and the pond configuration at Station 19 were all important to the differences in zooplankton fauna of Station 19 and the other Yellow Creek stations. The rotifer fauna of Yellow Creek was similar to that of the rest of the study area. The fauna included species characteristic of alkaline waters, and the species present (Notholca acuminata, Notholca squamula and Colurella adriatica) are considered tolerant of brackish water and even sea water (Remane and Schlieper, 1971).

Temperature was probably the most important factor in limiting the abundance of Notholca species in the Yellow Creek stations. Notholca is known as a cold stenotherm species which is intolerant of temperatures of 25°C or higher (Ruttner-Kolisko, 1974), although Carlin (1943) reported that in brackish water it apparently occurs in summer at high temperatures. The pond Station 19 showed little of the daily temperature fluctuations that was observed at the lower stations, and thus generally presented a more suitable habitat of Notholca species.

Throughout the year of study, the crustacean Eucyclops agilis occurred abundantly in Yellow Creek due to the continued presence of mature forms throughout the year, the species adaptability to widely changing temperatures, and its euryhaline characteristics (Rylou, 1948). Although Cladocera, in general, are restricted to freshwater areas of less than 1% salinity and so would not be expected in Yellow Creek; such species as Ceriodaphnia quadrangula, Chydorus sphaericus, and Simocephalus vetulus have been found to occur in salinities up

to 4 to 5% (Remane and Schlieper, 1971). The Cladocera found in Yellow Creek are typically summer species, thus accounting for their abundance in the August - September period. The differences in the relative abundance of Cladocera among the four Yellow Creek stations may be related to the density and type of aquatic vegetation. The higher relative abundance of Pleuroxus aduncus in Stations 20 - 22 may be correlated to the abundance of filamentous algae in Yellow Creek in late summer (Smirnov, 1971). The dense mats of Chara at Station 19 may account for the high population density of Alona circumfibriata, as affinities to Chara have been documented for Alona costata and Alona guttata (Quade, 1969), two species similar in size to Alona circumfimbriata.

The zooplankton fauna of Yellow Creek can serve as food for many of the filter-feeding or predaceous species of benthic invertebrates. Maximum abundance of predaceous cyclopoid copepods can be related to the increased abundance of their food, i.e., the rotifers and cladocerans, during the summer.

The diversity of the benthic fauna of Yellow Creek (annual mean Shannon index = 2.52) is also limited by the harsh chemical conditions which exist there. Those species which tolerate the harsh conditions, particularly the Simuliidae and Chironomidae, occur in great abundance. The dominant organisms in the benthic community were aquatic insects (particularly Diptera) and Oligochaeta. The number of Helobdella stagnalis (a leech), Lymnaea (a snail), and Hyalella azteca) a (freshwater scud) were found almost exclusively at Station 19, while Ceratopogonidae, Simuliidae, and Nematoda were common in sampling sites on Yellow Creek. The feeding habits of the most abundant benthic organisms included Simuliidae--detritus and algal feeders; Chironomini--carnivorous; and Orthocladiinae-algal or algal--detritus feeders. In general, in the Yellow Creek drainage (including the headwaters, tract, and lower Yellow Creek), opportunistic feeding, multitrophic level feeding, and changes in the niche at different life stages all contribute to the complexity of the food webs in these areas.

The primary source of autochthonous primary production in the White River was periphyton. Periphyton standing crops and species diversities (annual mean

Shannon index = 3.00) were higher in the White River than in any other study area. The factors which account for the larger standing crops and higher diversities included greater current velocities, more suitable substrates, and chemical conditions which were not as severe as those in the Yellow Creek drainage. The most abundant alga in the periphyton of the White River was the diatom Epithemia sorex. Other abundant alkaliphilous taxa included Lyngbya spp., Calothrix spp., and the diatoms Nitzschia dissipata, Nitzschia frustulum, Navicula salinarum var. intermedia, Navicula cryptocephala and Amphora ovalis var. pediculus. Organic weights of periphyton were generally highest in December 1974. Maximum cell densities occurred during mid to late summer above and below the confluence with Yellow Creek but during October - November 1974 and April 1975 at the confluence with Yellow Creek.

A comparison of the periphyton above, below and the vicinity of the Yellow Creek confluence suggests few differences attributed to Yellow Creek. Species composition was very similar in all three areas, although cell densities were lower at the Yellow Creek confluence. This was probably due to lower current velocities and less suitable periphyton habitat.

The phytoplankton constitutes a secondary source of autochthonous primary production in the White River. The species composition and abundance of phytoplankton was generally different from that of the headwater, tract or Yellow Creek areas. The phytoplankton of the White River contained a mixture of algae derived from both periphytic and planktonic habitats. In general, phytoplankton abundance was highest during the spring but lower than that in Yellow Creek. Phytoplankton abundance was expected to be lower because of the paucity of slack-water areas and the swift currents.

The paucity of lakes, ponds, pools, and backwater areas in the White River near the study area account for the low numbers of planktonic rotifers and limnetic Crustacea in the White River. The occurrence of Cladocera such as Alona, Pleuroxus, and Chydorus in the White River was not unexpected, since forms possessing compact, rounded bodies are better able to survive the turbulence of the river. However, as is the case with rotifers, the crustacean

fauna of the river is identical to that of Yellow Creek, suggesting that the river zooplankton may be the product of tributaries such as Yellow Creek. The low densities of zooplankton in the White River generally preclude its having significant importance as a food source.

The White River is characterized by a rubble substrate which provides many interstitial spaces as available habitat for benthic organisms. The benthic community of the White River was more diverse (annual mean Shannon index = 2.83) than any of the sampling areas of the Yellow Creek drainage, but densities of benthic macroinvertebrates were lower in the White River than in Yellow Creek itself. The increased diversity in the White River is due primarily to greater number of species and individuals of Ephemeroptera, Trichoptera, and Plecoptera. The major reasons for the increased benthic diversities in the White River are the increased number of habitats available, permanency and velocity of flow, and milder chemical conditions that exist in the headwaters, tract or Yellow Creek. Aquatic insects were generally the most abundant organisms, although the Oligochaeta were the most abundant organisms during the midsummer due to the emergence of many aquatic insects.

In the White River, the Ephemeroptera, Diptera, and Oligochaeta were the dominant groups. The most abundant Ephemeroptera included Ephemerella, Rhithrogena and Baetis. The dominant caddisflies belonged to the Hydropsychidae. Commonly occurring Plecoptera included Isogenoides, Isoperla, and Classenia. Small numbers of several other taxa of invertebrates were also found. The Oligochaeta of the White River were dominated by Tubificidae, Naididae, and Lumbriculidae. The feeding habits of the most abundant benthic organisms includes: Ephemeroptera--herbivorous; Hydrospsychidae--omnivorous; Plecoptera --opportunistic; Tubificidae--bacteria feeders; and other Oligochaeta--detritus feeders. The occurrence of opportunism, multi-tropic level feeding, and changes in the niche at different life stages all contributed to the complexity of the food web in the White River.

The greater species diversity, the increased number of species, and the high Evenness Index in the White River samples may also be due to food availability.

High algal biomass is recorded from the White River and algal-detritus feeders comprise the major component of the benthic community in the White River.

The ecology of the fishes of running waters was extensively discussed by Hynes (1970). He discussed the various anatomical adaptations and breeding and feeding habits exhibited by stream fishes as well as the biotic and abiotic factors that affect stream fishes. These aspects are discussed below as they relate to the fishes that occur on the RBOSP site.

Many fishes are well adapted anatomically for life in running water. These adaptations include streamlined bodies (either round in cross section or dorsoventrally flattened) and enlarged pectoral fins. Most of the fishes at the RBOSP site have streamlined bodies, including the abundant speckled dace and flannelmouth sucker which are round in cross section. This adaptation permits easier swimming in the fast water environment. A few species of fish at the site such as the carp and red shiner have body forms characteristic of fishes of slow-flowing waters (i.e., laterally flattened). These species are introduced and are not abundant. They may never become abundant due to competition with native species that are well-adapted to the fast water environment.

The mottled sculpin is very abundant in the White River at the RBOSP site and is admirably adapted for life in fast-flowing waters, although not particularly for swimming in running water. The mottled sculpin is dorsoventrally flattened and has large, muscular pectoral fins. These characteristics enable the fish to hold its position on the bottom in fast water.

Oxygen is one of the most important ecological factors affecting fish. However, Hynes (1970) points out that critically low oxygen concentrations are less a factor in running water than in still water due to the rapid rearation capabilities of running water. This circumstance was borne out at the RBOSP site where oxygen concentrations in the White River were never far below saturation during the study period.

Water temperature is another environmental factor that has a bearing on the presence or absence of a given fish species at the RBOSP site. On the basis of water temperature, the White River at the RBOSP site could be characterized as a "cool water" habitat. The mottled sculpin is abundant at the site and is said by Beckman (1952) and Miller (1964) to prefer cool to cold mountain streams. The various trouts and the mountain whitefish are cold-water species and also occur at the site, but in low numbers. However the presence of other species commonly associated with warm water habitats such as carp, channel catfish, red shiner and, presumably, flannelmouth sucker suggest the intermediacy of the habitat with regard to temperature.

As a further example of the "intermediate" water temperatures at the RBOSP site, it appears that the optimum water temperatures for trout are exceeded in some years. Maximum summer water temperatures of the White River at the RBOSP site in 1973 and 1975 were 15.3^{o}C (Pennak, 1974) and 21.0^{o}C (present study), respectively. These temperatures are within the preferred ranges of rainbow and brown trout (McAfee, 1966; Scott and Crossman, 1973). However, a temperature of 24^{o}C was reported for the White River near the RBOSP site in summer, 1969 (Everhart and May, 1973). This was in excess of the upper preferred temperature of rainbow trout and at the upper preferred limit of brown trout. Therefore, the low numbers of salmonids at the site may be due, at least in part, to above optimum summer water temperatures occurring during some years.

The relationship of dissolved solids to the growth of fish, particularly trout, has been much studied (Hynes, 1970). The fact that growth of trout is much greater in hard water than in soft water has been well established, but the reason for this has not been determined. The hard waters of the White River at the RBOSP site (140 - 340 mg/l as $CaCO_3$) precludes restrictions of fish growth due to dissolved salt deficiencies. The fish growth studies conducted to date (see section 8.F - 4.C) have revealed no unusually low growth rates.

Although dissolved solid concentrations are high in the White River and very high in Yellow Creek (up to 919 mg/l hardness as $CaCO_3$ in Yellow Creek), the levels are not high enough to be deleterious to fish. McKee and Wolf (1963)

reported that the limiting concentrations of dissolved solids for freshwater fish are probably in the 5,000 - 10,000 mg/l range. This is well in excess of the maximum values recorded for the study area. Of the ionic constituents of dissolved solids, only sodium occurred at levels that are possibly detrimental to fish. The maximum recorded value for sodium at the site (977 mg/l) occurred in lower Yellow Creek in April, 1975. Some fish mortality has been experienced at sodium levels of 500 - 1,000 mg/l (McKee and Wolf, 1963). However, nearly the highest levels of sodium and other dissolved solids were recorded in lower Yellow Creek during May - June 1975, at a time when large numbers of fish were present, apparently unaffected by the relatively high concentrations of dissolved solids.

In discussing the substratum of streams, Hynes (1970) pointed out the importance of shelter to fish. For example, trout occur more abundantly where there are more hiding places. This is important regarding the RBOSP site since long stretches of the White River have little suitable shelter, such as large rocks and boulders or logs. What shelter exists is in the back channel areas (formed by islands) and, consequently, the nine trout captured to date at the RBOSP site were taken in back channel areas. This may be another factor contributing to the low numbers of trout in the study area.

The waters of the White River carry a high silt load (peak in April during present RBOSP study) that is apparently due to high alkalinities and clay content of the streamside soils in the area (Pennak, 1974). The substrate in the main channel areas of the river is free of silt but slow-flowing backwater areas have deep silt deposits. Survival of trout eggs would be improbable in this type of habitat. This is perhaps the most important reason for the low numbers of trout in the area. In contrast, the flannelmouth sucker is well adapted to the silty conditons, having evolved in the historically turbid Colorado River, and is thus a dominant species in the study area.

Reproduction of fishes at the RBOSP site takes place in the spring or summer, with the exception of brown trout and mountain whitefish which spawn in late

fall or early winter. Onset of spawning is controlled by water temperature and photoperiod (Andreasen and Barnes, 1975), and stream discharge (Hynes, 1970).

Of the common fishes at the RBOSP site, reproductive habits have been described for only fathead minnow and mottled sculpin to any extent. Spawning of mottled sculpin takes place in May or June (Hynes, 1970; Bailey, 1952) and in June possibly extending through the summer for the fathead minnow (Hynes, 1970). Both species deposit adhesive eggs on the underside of rocks or other suitable material which are then guarded from predation and/or siltation by the male. Such adaptations certainly contribute to the abundance of mottled sculpins in the study area and could possibly assist the fathead minnow in establishing itself in the area.

Information on reproductive habits of other common species is nonexistent or sketchy. The flannelmouth sucker is abundant at the RBOSP site and many other parts of the Colorado River drainage, yet reproductive biology of the species has not been reported in the literature. During the present study of the RBOSP site, it was determined from gonad examinations of flannelmouth suckers in April and June, 1975 that spawning apparently took place sometime in May or June, probably mid or late June, at water temperatures of about 12 - 13^{o}C. Large numbers of young-of-year flannelmouth suckers appeared in the catch for the first time during the early September, 1975 sampling. Insufficient numbers of sexually mature bluehead suckers were taken at the RBOSP site to yield information on reproductive biology. However, Andreason and Barnes (1975) reported that bluehead suckers spawned from May through early July in the Weber River, Utah through a water temperature range of approximately 5 - 10^{o}C. The preferred spawning habitat for the flannelmouth and bluehead sucker is probably relatively clear riffle areas where the eggs are partially buried in gravel during the spawning act (as with other members of the genus *Catostomus* according to Hynes, 1970). The reproductive habits of the speckled dace, the most frequently captured species at the RBOSP site, have not been described in detail (Minckley, 1973). Other members of the genus *Rhinichthys* sometimes form nests for egg deposition. The preferred spawning habitat appears to be riffles (Minckley, 1973).

It is clear that each successful fish species at the RBOSP has its own peculiar spawning adaptations that ensure survival of eggs and young in the swift, turbid water environment. The adhesive eggs of the fathead minnow and mottled sculpin protect against displacement and the guarding males assist in keeping the eggs free of silt. The act of burying many of the deposited eggs by the suckers and probably the speckled dace precludes displacement by the current and the location (riffles) insures that the eggs will be kept clear of silt by the current.

The interaction of fish with other biological groups in the environment is most obviously manifested in the feeding habits of the fishes. Food habit studies of major species at the RBOSP study area and literature information indicates that the species present feed primarily on benthic invertebrates, primarily immature insects of the family Chironomidae and orders Plecoptera, Ephemeroptera and Trichoptera. Hynes (1970) indicated that invertebrates constitute the most important foodstuff of running water fishes.

Although there is considerable overlap of feeding habits among the fishes, sufficient differences exist to prevent direct competition between species. Both the flannelmouth and bluehead suckers ingested immature insects. However, the May - June 1975 stomach content analysis of bluehead suckers, in conjunction with the specially adapted mouth and intestine of this species, indicate a primarily herbivorous feeding mode; thus the classification of this species as a primary consumer. The flannelmouth suckers fed largely on immature insects and ingested significant amounts of plant material only in June and July.

Changes in fish diets with the seasons is brought about by food availability. This was illustrated by the decrease from spring and summer in immature insects and increase in algae and plant material in flannelmouth sucker stomachs following similar changes in the environment. Seasonal diet changes were also recorded for the mottled sculpin. Stoneflies of the genus Isoperla were important in the sculpin diet only in April, the only time they occurred in significant numbers in the benthos samples. Also, occurrence of

hydropsychids in sculpin stomachs generally paralleled their abundance in the environment.

That diets change with the size of fish of a given species is also well established; however, no attempt was made to quantify this in the present study. One obvious case of diet change with increased fish size was seen in the present study; fish first occurred in the diet of some mottled sculpin that were larger than 80 mm.

Thus, the energy utilized by the fishes of the RBOSP site is obtained through several pathways. The primary pathway probably passes from allochthonous or autochthonous organic matter to immature insects to fish. A greater degree of complexity is introduced by the fact that aquatic insects exhibit a variety of feeding modes. The Ephemeroptera are primarily herbivorous, the Odonata and certian Chironomidae are carnivorous, the Plecoptera are ominivorous and other are detritivorous. So although fish are generally considered secondary consumers, they could technically be considered either primary, secondary, tertiary or quaternary consumers, depending on the organisms they ingest. The most common food items found in the White River fish stomachs were Chironomidae, _Baetis_ and _Ephemerella_ (Ephemeroptera), _Hydropsyche_ (Trichoptera) and, to a lesser extent, _Isoperla_ (Plecoptera). Of these organisms, only _Isoperla_ feeds to any extent on animal matter, making it secondary consumer

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CHAPTER 9

SEISMICITY

CHAPTER 9

SEISMICITY

A seismicity investigation of the Piceance Creek basin was performed to determine the extent of seismic activity in the Tract C-a area due to earthquakes. The investigation, consisting of a literature search, was performed by Dr. E. D. Alcock, consultant to RBOSP. Various governmental and private organizations aided in establishing both recorded and reported seismic events in the area, the results of which indicate that the Piceance Creek basin appears to be an area of low seismic activity.

9.1 EARTHQUAKE DISTRIBUTION

The seismic risk map, Figure 3-9-1 (Algermissen), shows that all of the Piceance Creek basin is a quiet seismic area and is classified as Zone 1. Structures in this zone built to withstand fundamental periods greater than 1.0 sec can be expected to suffer no more than minor damage from large distant earthquakes. This opinion of the seismic activity of the area is also held by Mrs. Ruth Simon (Simon, 1969, p. 897-899) and Dr. Frank Stead (personal communication) both of the U. S. Geological Survey. Maps of seismic activity in Colorado issued annually between 1966 and 1971 (Simon, 1966-1972), show that the only earthquakes (magnitude 2 or greater) in Colorado within 40 miles of Tract C-a were at the Harvey Gap Reservoir and at Rangely. The last available map (Simon, 1972) shows the same seismicity for the basin. Those events at the Harvey Gap Reservoir are believed to have been due to the effect of the loading by the stored water (Simon, 1969, p. 897-899) on the underlying geologic structure. Those events at Rangely have been postulated to result from the water flooding of the Rangely oil field (Raleigh, Healy).

A search was made of the National Oceanic and Atmospheric Administration (NOAA) historical seismic data in an area within 50 miles and 100 miles of Tract C-a. This search covered the period from 1941 to 1975 for earthquakes greater than

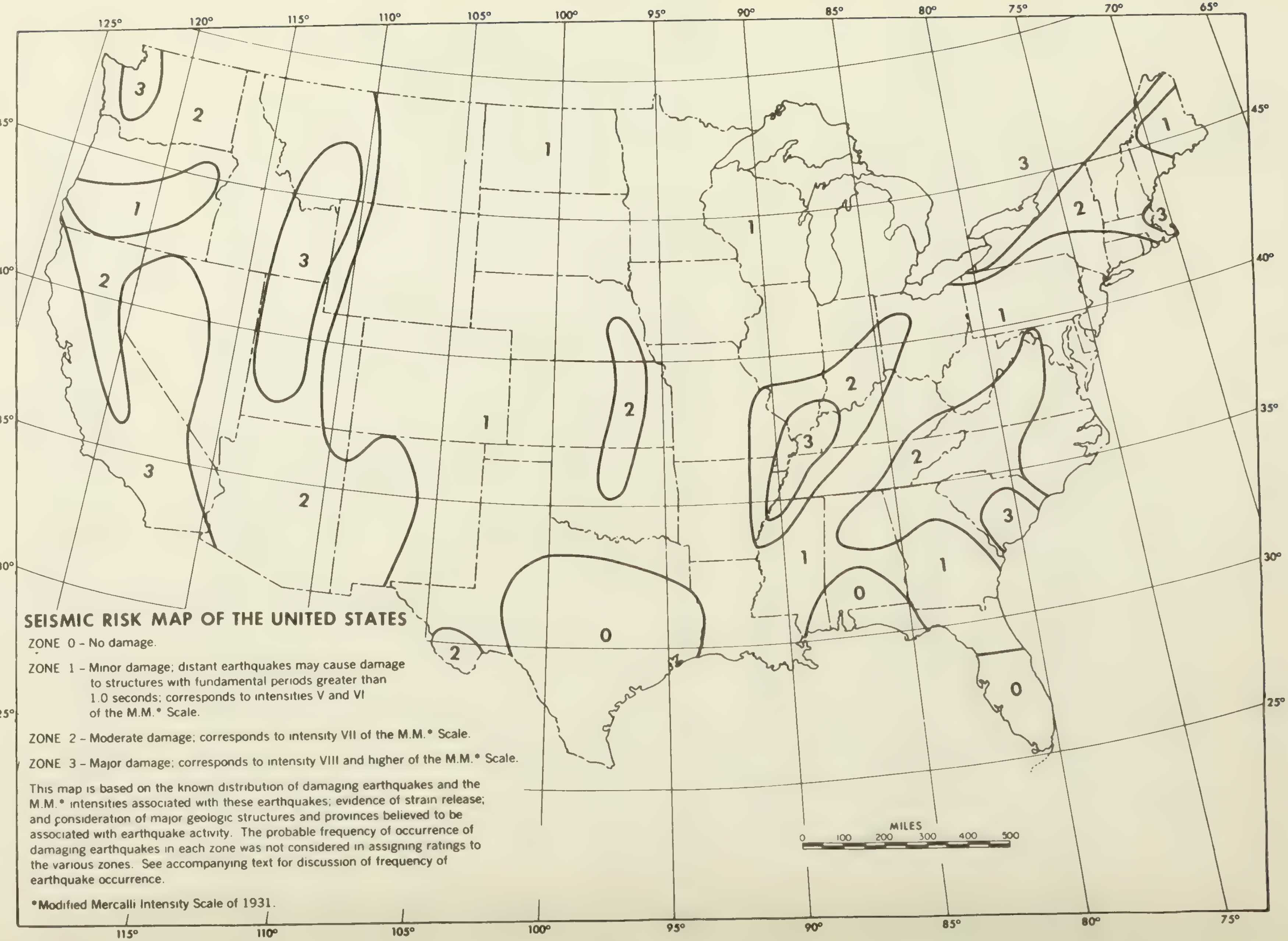

Figure 3-9-1

SEISMIC RISK MAP OF THE UNITED STATES

magnitude 3. The results of this search are shown in Figure 3-9-2. The Harvey Gap Reservoir events are not shown because they were lower than magnitude 3.

CER Geonuclear Corp. operated a seismic station in connection with its Project Rio Blanco (a nuclear gas stimulation project) from November 20, 1971, to December 17, 1973. This station was located in Sec. 28, T2S, R98W, only about 10 km from Tract C-a (CER Geonuclear Corp., 1974). Aside from the earthquake and aftershocks resulting from the detonation of Project Rio Blanco, only 2 micro-earthquakes (local magnitude less than 1) were recorded within 40 km of the station during this period.

In preparation for the seismic investigation of the Rangely oil field, the U. S. Geological Survey made a search of seismic data recorded for a 7-year period at the Uinta Basin Observatory for earthquakes originating near the oil field, 65 km ESE of the observatory (Gibb, et al, 1973, p. 1557-1570). This search covers the area in which Tract C-a lies and shows no more than one earthquake of local magnitude greater than 1 in the 7-year period. This seems to be in close agreement with the results from the CER seismic station.

9.2 CRUSTRAL STRESS

Strain release data of the United States indicate little probability of any strain stored in the subsurface in the Tract C-a area to cause earthquakes. In preparation for Project Rio Blanco, several calculations of subsurface stress existing at various points in the Rio Blanco Unit area were made using Kehle's method of determining the stress from hydraulic fracturing data (Kehle, 1964). In all cases, the principal stress was compressive and vertical, and within the limits of the method, equal to the lithostatic pressure. There was no evidence of any significant horizontal stress.

9.3 CONCLUSION

In view of the available data reviewed, it is believed that the seismicity of the Tract C-a area is low, a fact that is well documented. Sanford and Singh

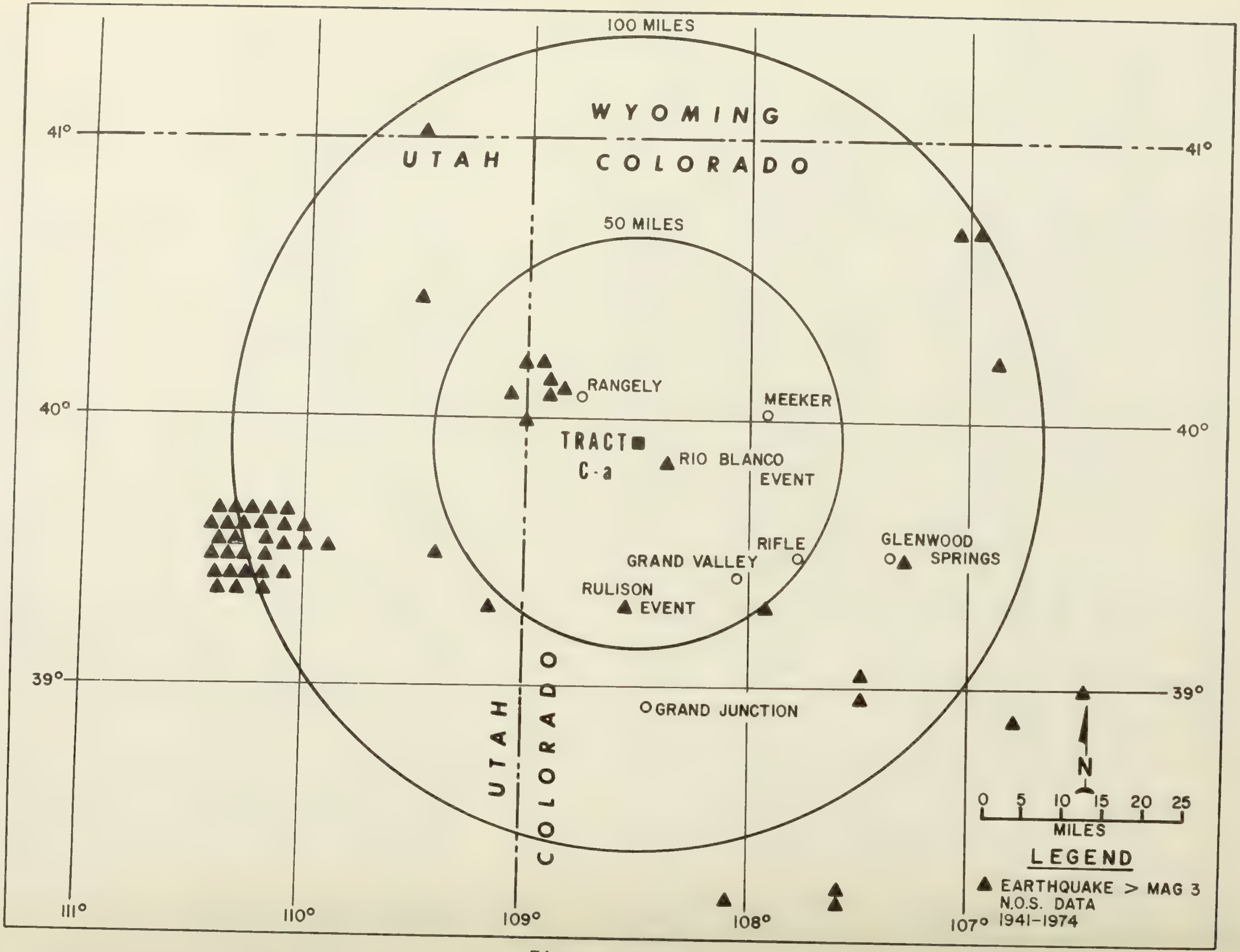

Figure 3-9-2

SEISMIC ACTIVITY OF GENERAL TRACT C-a AREA

(1968, p. 639-644) have shown that, in general, about six months of recording will give a reliable estimate of the earthquake-frequency relation from which short-term (10 years) seismicity is calculated.

9.4 REFERENCES

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CHAPTER 10

ARCHAEOLOGY

SECTION 3

BASELINE CONDITIONS

The archaeological resources of federally administered lands must be investigated prior to any physical disturbance of the land as stipulated by the Federal Antiquities Act of 1906 and other more recent legislation (Lipe and Lindsay, 1974). The permit (#75-CO-047) for archaeological investigations on Tract C-a and surrounding areas was granted by the National Park Service, Department of the Interior. Permits are granted for research on federal lands and local administration of the permit and special stipulations are supervised, in this case by the Bureau of Land Management.

Initial RBOSP archaeological investigations on and near Tract C-a began in the summer of 1974 and were confined to the areas of proposed instrumentation stations, drilling locations, and access roads.

Later, between June and October of 1975, an intensive survey was conducted on the tract, the proposed 84 Mesa disposal area, and a 1-mile perimeter around the areas. Adjacent areas were also investigated, particularly downstream from the tract on the various drainages leading into Yellow Creek.

10.1 OBJECTIVES

The purpose of the survey was to recover as much archaeological and historical material as possible; to establish which locations should be considered for more intensive archaeological investigation; and to determine if any sites are eligible for nomination to the National Register of Historic Places in compliance with criteria set forth in the Federal Register 41:28, Part II, Feb., 1976. Knowledge of the location of sites makes it possible to avoid destruction of artifacts during construction. The survey was designed to obtain information on the length and extent of occupation, cultural affiliations of people in the area, and the nature and degree of historic exploitation of the region.

10.2 METHODS

Initial archaeological surveys were confined to drill pads, road sites, and instrumentation stations prior to disturbance during construction. No significant material was found in these localized areas and the surveys were limited to surface examinations only.

The extensive, area-wide survey was conducted later by two teams consisting of five or six people who systematically walked over the survey area. Areas that appeared to have a potential for occupation such as benches adjacent to drainages, springs or streams, and upland areas that had possibly been used for hunting and gathering were intensively searched.

In relatively featureless terrain such as 84 Mesa and other uplands, team members were spaced a short distance apart and linear traverses were made.

The survey was concentrated in the areas shown in Figure 3-10-1. This figure shows the expanded survey area to the northeast and locations of primary and secondary sites found there. After the survey had progressed sufficiently, information gathered in the field was processed. Types of artifacts obtained were itemized and locations of sites mapped. The emerging pattern of site locations was used to direct the investigation into areas where the possibility of finding additional sites appeared the greatest.

Material recovered in the field was processed in the base station laboratory. Artifacts were washed, given a field number that corresponded with a particular site location, identified, and listed. Locations of both artifact-producing areas and non-producing areas were plotted at the end of each field day.

A total of 197 locations produced archaeological material that had been transported into the area or modified in some way by man. Further analysis is currently in process at the Archaeological Laboratory at the University of Denver. The typology of the artifacts is being refined and classification and identifications are being made which will allow the material recovered on Tract C-a to be compared with similar material found in nearby regions reported

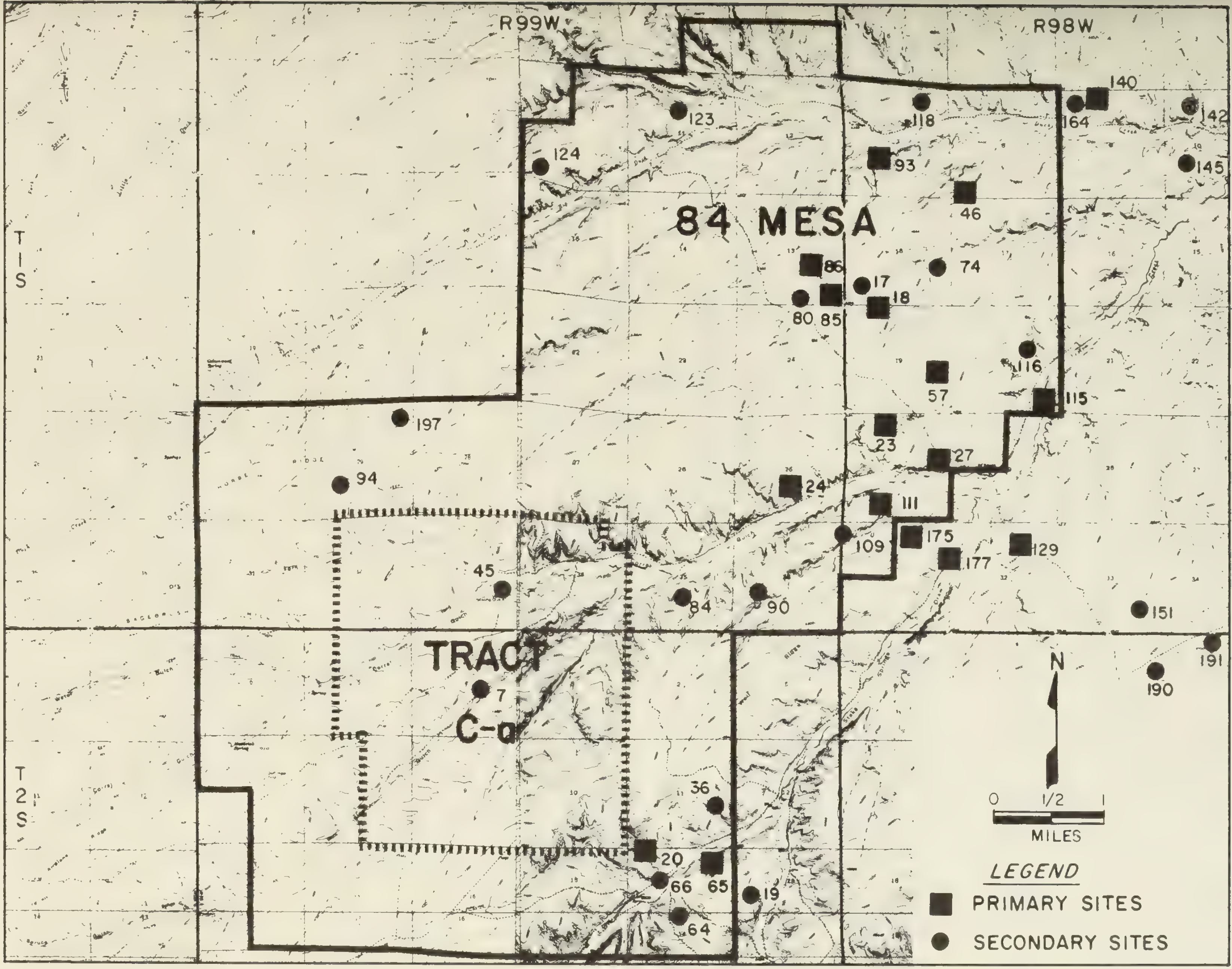

Figure 3-10-1

PRIMARY AND SECONDARY ARCHAEOLOGICAL SITES ON TRACT C-a, 1-MILE PERIMETER AND 84 MESA

in the literature and private collections. At present, the significance of clustering of sites in relation to National Register Criteria, is being examined and the likelihood of further yield of material with excavation is being explored. This information will be used to make nominations to the National Register, if any, and will be forthcoming shortly.

10.3 LITERATURE REVIEW

C. Jennings (1974) conducted a survey and limited excavations in the Piceance Basin in 1973 and 1974. These investigations were supported by both Thorne Foundation of Boulder, Colorado and Colorado State University. The project was directed to obtain information on the impact of oil shale development on the archaeological resources of the basin and adjacent areas. The survey was extensive, including portions of both Tracts C-a and C-b and a section of the Douglas Creek drainage. A randomly selected sample of 48 land survey sections was intensively examined.

Jennings (1974) reported four sites within the vicinity of Tract C-a that he considered archaeologically significant. Two of these were located on the southeast corner of the tract. The other two were located several miles east of the tract along Corral Gulch Road near 84 Ranch. He based the importance of the tract sites on the presence of concentrations of stone tools and chips associated with fire pits (unpublished data presented to Gulf Minerals Resources Company 1974). In addition, he found the fragment of a Paleoindian projectile point believed to be quite old ($\sim$6000 B.C.) at one of these sites. He recommended both of these sites for excavation.

The third site reported as important by Jennings is off tract (several miles east along Corral Gulch Road) and not subject to disturbance by construction activities. Its importance is related to the high yield of artifacts and the presence of several fire pits. He recommended further study of this site.

The last site considered important by Jennings was the area known as 84 Ranch. It is also several miles off tract to the east along Corral Gulch Road. This is a historic site supporting several log outbuildings, a masonry ranch house,

and a modern corral. It probably represents the early part of the Twentieth Century up to the mid-1900's. He recommended further study to document the importance of the area as a cattle-raising region.

All other sites in the vicinity of Tract C-a were classified as either "simple chipping stations" or "less regularly used camps" and were not recommended for extensive study (unpublished proposal submitted to Gulf Mineral Resources Company, 1974).

Wenger (1956) investigated the Douglas Creek drainage and several sites in the Blue Mountain area north of Rangely, Colorado. These areas support protected shelter areas and substantial amounts of rock art, both painted on and pecked into the rock surfaces. A great deal of this rock art was produced by people of the Fremont Culture period, although earlier peoples could have been responsible for some of it. The natural protection afforded by areas such as this allows the preservation of organic material which would be destroyed at sites exposed to the elements. Wenger stated that the artifacts he found were related to the Fremont Culture and to later peoples such as the Ute. Artifacts found in the area included stone artifacts, wooden and bone tools, basketry, various items made from cordage such as snares for small mammals, and pottery of several varieties.

The material recovered during the survey can be compared with several adjacent areas within western Colorado and nearby portions of the Great Basin. No organic material was collected during the survey; therefore, no direct carbon dating could be done to identify stratigraphic placement or the exact relationship to other artifacts.

The Great Basin and its peripheral areas have received considerable archaeological attention. This region includes the plateaus, basins, and ranges that lie between the western coastal ranges and the Rockies from Canada to Mexico. Dry caves and shelters occur in many portions of this area. The preservation of material in these caves has allowed reconstruction of prehistoric culture patterns.

J. Jennings proposed the term Desert Culture or Western Archaic (Jennings, 1957) for the particular cultural adaptations found in the central portion of the Great Basin, particularly Utah. Several sites, including Danger Cave, Juke Box Cave, and Raven Cave produced material for his definition of this cultural horizon. Of the three, Danger Cave was the most important. Similar Archaic material was reported from Hogup Cave and other sites (Aikens, 1965; Anderson, 1956; Fowler, 1968; Jameson, 1958). Hester (1973) postulated that the Great Basin had a relatively unchanging cultural continuum that lasted from approximately 10,000 B.C. until the time of European contact (1850 A.D.) in some areas. The people of the area ate both plants and animals as they became seasonally available. Material possessions were light in weight and portable to conform to a migratory life style. A number of non-breakable containers such as woven and hide bags and baskets was used. Baskets covered by pitch were used for water containers. The use of pottery did not evolve until late in the continuum. Tools reflect a hunting and gathering culture and include a large variety of projectile points, scrapers, knives, and grinding stones used to process plant material. The overall population density was low, with people living in small groups. This period lasted in most areas until the early centuries of the Christian era (500 A.D.).

The University of Colorado conducted a survey and excavations in Dinosaur National Monument (Burgh and Scoggin, 1948; Lister, 1951; Breternitz, 1970). Breternitz reported that occupation began with either Plains or Western Archaic influences, perhaps as early as 7000 B.C. The occupation at Dinosaur Monument apparently lasted through the Fremont Culture period (beginning around 1000 A.D.) to historic times.

The Fremont period was defined by Morss (1931). Pottery was introduced, marginal agriculture was practiced, small pithouse villages were built, and hunting and gathering continued to be important. This period may have begun as early as 500 A.D. in some portions of the Great Basin. Most stone tools were unchanged from those used during the Western Archaic Culture, but changes in projectile points did occur. Grinding stones, presumably used for the processing of corn as well as native plant material, were used. The most common type of pottery was an unpainted ware tempered with crushed stone such

as calcite, siltstone, or igneous rocks. Alterations or decorations of the surface such as corrugation and incising were used, but painting was rare. Painted pottery was imported from other areas, particularly from the south. The data of termination of the Fremont Period has not been determined, nor is the relationship of the Fremont Period with historic groups that were found in the Great Basin at the time of European contact known. Their origin is not clearly established. They may have merely been Great Basin peoples who adopted traits introduced from the Puebloan people from the south or they could have migrated into the area from the north and accepted pottery and agriculture. Date of termination of the Fremont Period is not clearly defined, but may be around 1500 A. D.

Between 1947 and 1952, the University of Colorado excavated several sites on the Uncompahgre Plateau in west-central Colorado (Wormington and Lister, 1956). These shelters produced a considerable amount of perishable material. From their analysis, they defined the "Uncompahgre Complex" which was compared with the latter portion of the Western Archaic and ended in the late centuries prior to 1 A. D. Pottery was lacking and there was no evidence of farming. Comparisons of artifact types were made with material from Dinosaur National Monument. Distinctive artifact types included projectile points with indented bases and dry material that matches similar material found in the Great Basin.

10.4 DATA SUMMARY AND DISCUSSION

A total of 197 archaeological sites was discovered during the survey. These sites contained material that was transported into the area or modified by man. The archaeological material ranged from a single flake of toolstone to concentrations of a large number of broken, discarded, or lost tools and the wastage associated with their manufacture. Three classes of site importance were established-primary, secondary, and tertiary. Ranking the sites was somewhat subjective but an attempt was made to design a system based on the occurrence of types of tools and their relative frequency at a given site that would be compatible with criteria set forth in the National Register.

Factors considered included the number of artifacts, presence of structures, and any other evidence of occupation. The length of occupation can be inferred from the variety of tools, and by the extent and geography of the area where the tools are found. All of these factors were considered when assigning a site class designation to a particular site.

Primary sites were described as having the largest number of tools and other artifacts. These are sites that may have been reoccupied seasonally and included structures and sites which covered a relatively large area. Only six sites supported structures. These were standing frameworks or the collapsed remnants of tipi-like structures (wickiups) made out of juniper branches. These six sites were put in the primary classification even though the artifact collections were small. On sites of this classification, it is possible that the numbers of artifacts could be increased by excavation and that subsurface features such as houses, fire pits, or other modifications could be found. Locations of primary sites are shown on Figure 3-10-1.

Secondary sites had less material than primary sites. Some of these sites might provide more information with excavation. They appear to represent a very short period of occupation. They contain material that was used or discarded during a single camping period, probably for the utilization of a resource such as game animals or perhaps a gathering operation. Structures may also have been present at these sites, but would probably be less likely than the sites that have more material. Sites of this class would have a low priority for excavation but should be avoided during construction and development if possible. Locations of on-tract, 1-mile perimeter, and 84 Mesa sites are shown on Figure 3-10-1.

Tertiary sites are represented by very few artifacts, a few chips of toolstone, or a discarded or lost artifact. While they indicate man's use of the region, they probably do not represent camp sites.

Primary and secondary sites might produce more material with excavation or after erosion has uncovered additional artifacts. Tertiary sites probably would not produce more material. The number of archaeological sites found

during the survey, type of site, and general location are presented in the following table. Additional information on site designations will be available in a supplemental report to the BLM in the near future.

NUMBER, LOCATION, AND CLASSIFICATION OF ARCHAEOLOGICAL SITES FOUND DURING SURVEY OF TRACT C-a, RBOSP

	Location			
Classification	Tract C-a	84 Mesa	1-Mile Perimeter	Off-Tract*
Primary	0	11	2	9
Secondary	2	9	6	16
Tertiary	20	41	29	52
Totals	22	61	37	77

*Sites off-tract other than 84 Mesa or the 1-mile perimeter sites.

No primary and only two secondary sites were found within the boundary of Tract C-a during the current survey. However, Jennings (1974) reported two sites on Tract C-a which he considered to be of archaeological significance. These areas are in the vicinity of Site Numbers 39 through 42 (Table 3-10-1). Due to the duplication of archaeological finds in these areas and the importance assigned to the area by Jennings, the classification of these sites is subject to change as analyses and comparisions are completed.

The material used for chipped tools found in the area included siliceous rocks such as chalcedony, jasper, petrified wood, obsidian, and quartzite. These materials are fine-grained and can be worked by percussion flaking (the material is struck by a stone or a piece of antler to shape the tool to the desired form). Pressure flaking, where smaller flakes are pressed off usually using an antler tine, was used for finer work and the finishing of artifacts. During tool production, the chips or wastage was discarded if the flakes were not large enough to be used for other types of tools. This wastage indicated that the study area was occupied for some time rather than just during movement through the area. The color and texture of this toolstone is quite different from

the local shales which indicates that it had been transported into the area. This was probably because local stone was not easily worked and was not suitable for small stone tools. Local stone was used for larger stone tools such as choppers or grinding tools. Suitable stone occurs in alluvial deposits in the White River drainage, Utah, and southwestern Wyoming.

Tools used for grinding or crushing various vegetal products were also found. The lower element of these tools, the grinding slab or metate, was usually an oval or irregular slab of local sandstone (Fibure 3-10-2) in which a depression had been worn through use. The handstone, or movable element, was usually fashioned from a small, oval stream cobble. These were of a size that could be conveniently held in one hand. Evidence from the historic period indicates that these tools were used to grind various types of seeds, to shell pinyon nuts, and, in some instances, to grind meat. Cooking techniques included preparation of varieties of liquid or mush-type foods. Another use of these tools was to grind pigments that could have been used for body painting, decoration of household equipment, or pictographs.

The sites that were found during the survey are classed as open sites. These are in open areas with no physical protection other than variations in topography. Only a few caves or overhangs were found and these did not appear to have been occupied. Since most camp sites were in the open, good weather was probable. Open sites such as the ones found in the survey area usually yield only stone artifacts because insect or bacterial action and oxidation quickly destroy all but the most durable materials. In prehistoric times, tools were made from a number of perishable materials such as bone, antler, horn, and a number of vegetal materials. None of these materials was collected from the survey area. However, unworked bone is scattered throughout the area. This was probably left behind by contemporary hunters or winter kills. Several types of artifacts were collected, including projectile points or "arrowheads", knives, scrapers, grinding tools, and pottery.

These tools are diagnostic of the cultures using the area because their shapes change through time. Projectile points are perhaps the most important tools for comparison. They are both regionally and temporally distinctive. Almost

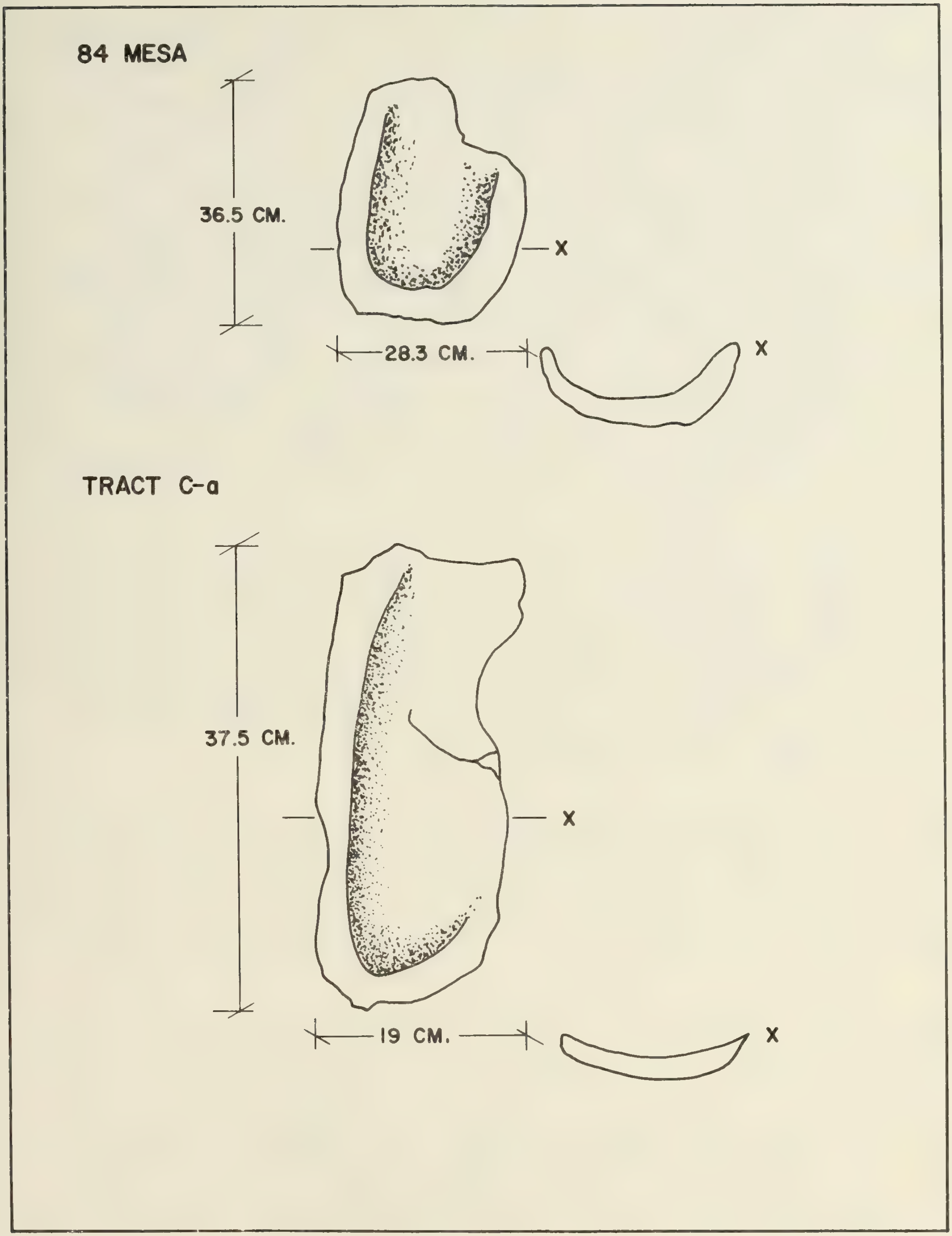

Figure 3-10-2

METATES FOUND DURING RBOSP ARCHAEOLOGICAL SURVEY

all the pints in the collection are modified at the base or stem of the point to facilitate attachment to the wooden shaft. The projectile points in the collection exhibit careful workmanship and chipping on the edges and faces (see Figures 3-10-3 to 3-10-5).

Blades and knives, chipped on both sides of the edge to provide a cutting edge, were used primarily as processing tools for cutting meat, hides, or working other materials such as wood. Two distinct types were found. One was a finished tool chipped to a particular outline and generally larger than projectile points. The other was merely a flake large enough to be held in the fingers. These were used until they became dull, then discarded without further modification. These flakes are sharper than a flaked knife but the edge is very thin and not durable. Types of finished knives are shown in Figures 3-10-6 and 3-10-7.

Other artifacts found include scrapers which were used to prepare hides and to make non-lithic artifacts. The edge of a scraper, unlike a knife, was chipped away from only one flat side to produce an angular edge. Small chips or flakes found in the area were called random flake scrapers. The majority of scrapers found (Figure 3-10-8) were too small to have been attached to a handle and were probably held in the fingers.

Flakes, or evidence of tool manufacture, were also found. Even though the flakes were used for knives or scrapers, they are not good diagnostic artifacts because their shapes do not change with time. However, their abundance and distribution are good indicators of the level of occupation at a given site.

Other material found included metates (grinding slabs) and manos (handstones) which were used for grinding various materials. Drills and punches were found which are similar to tools in our culture except that they were made of stone. Cores, the remnants of toolstone from which flakes have been removed, were collected but not classified as tools. Hammerstones, spherical pieces of durable stone, were used by people of the basin to chip stone and to shape manos and metates. Choppers (defined as large chipped-edge tools that were

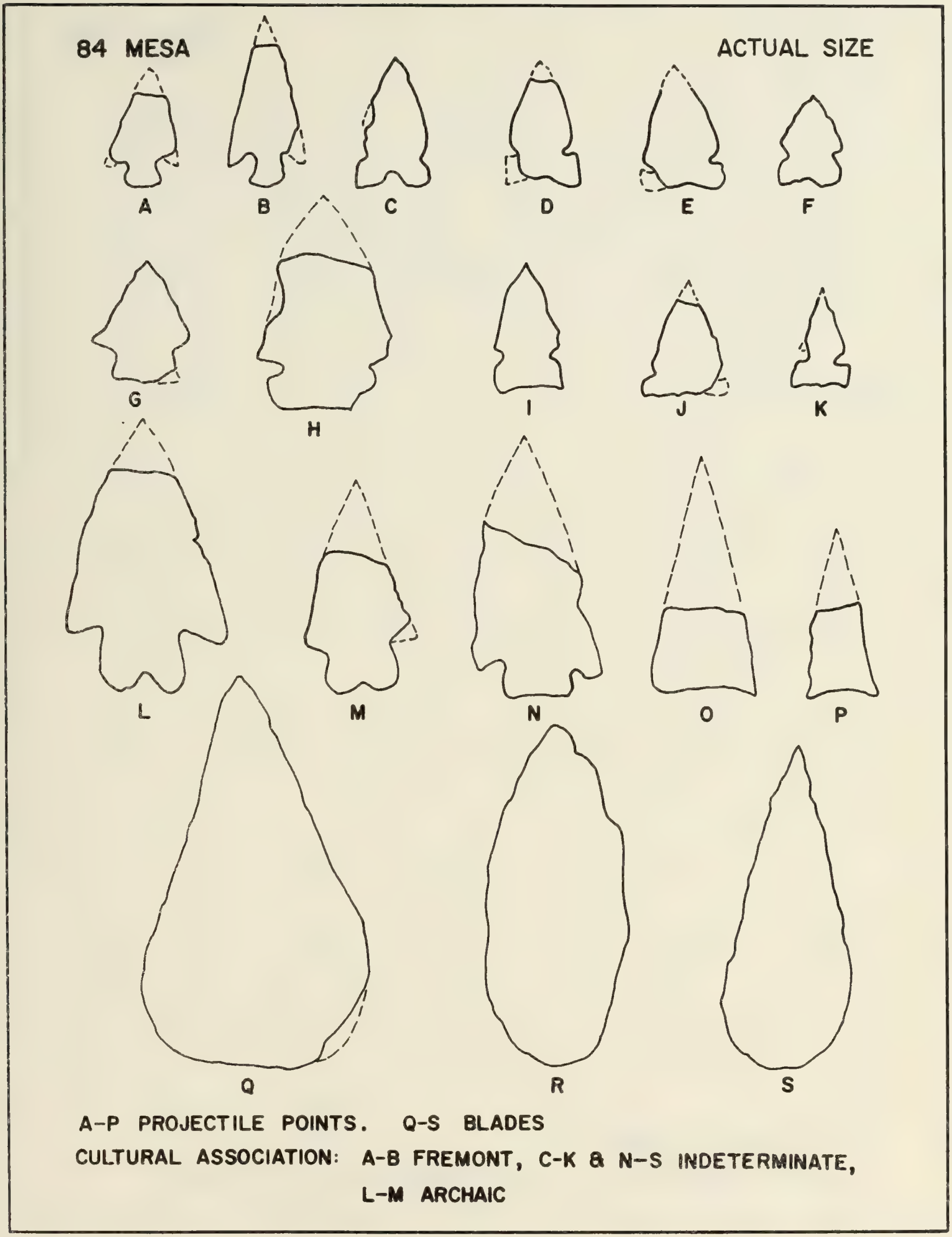

Figure 3-10-3

PROJECTILE POINTS AND BLADES FOUND DURING RBOSP ARCHAEOLOGICAL SURVEY

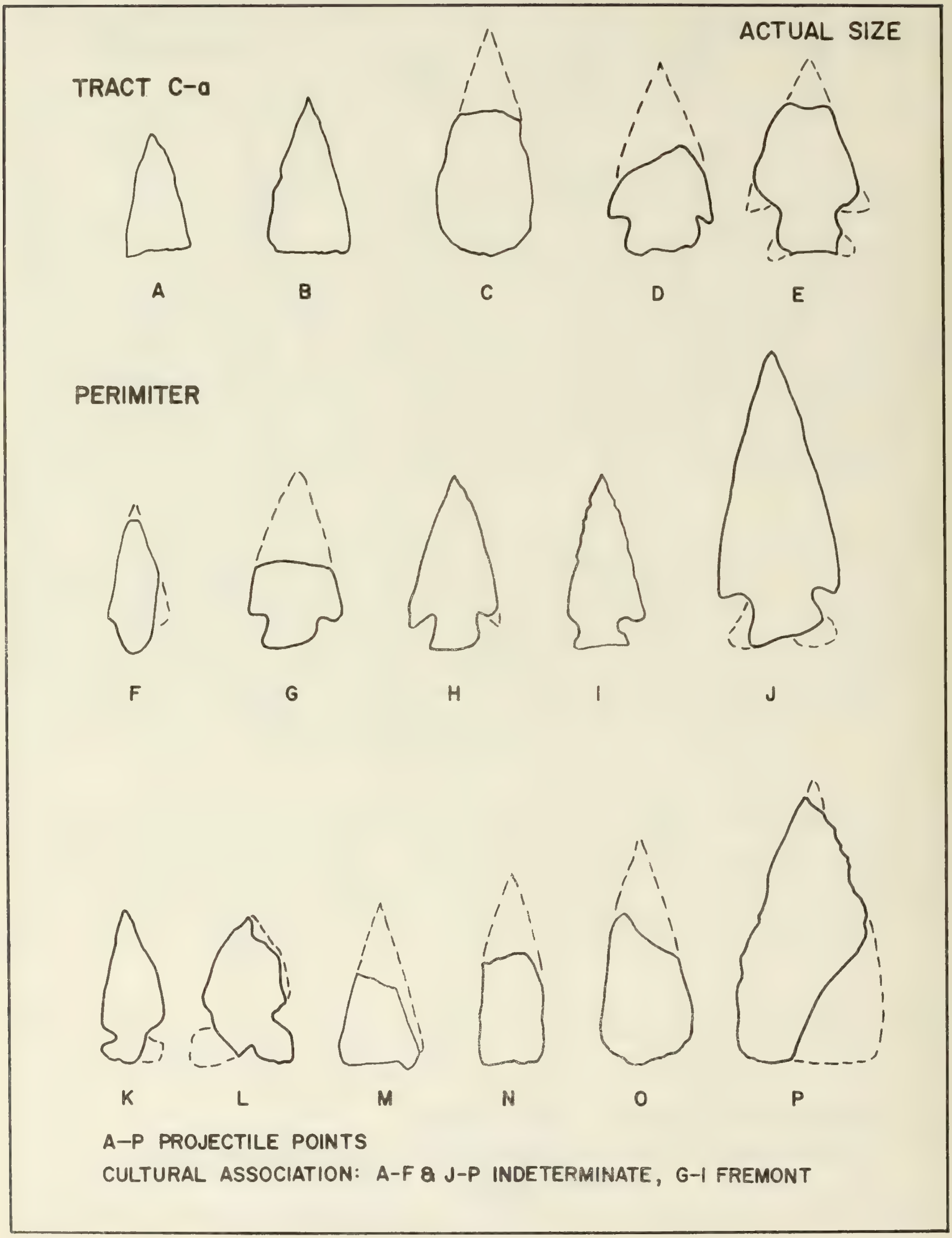

Figure 3-10-4

PROJECTILE POINTS FOUND DURING RBOSP ARCHAEOLOGICAL SURVEY

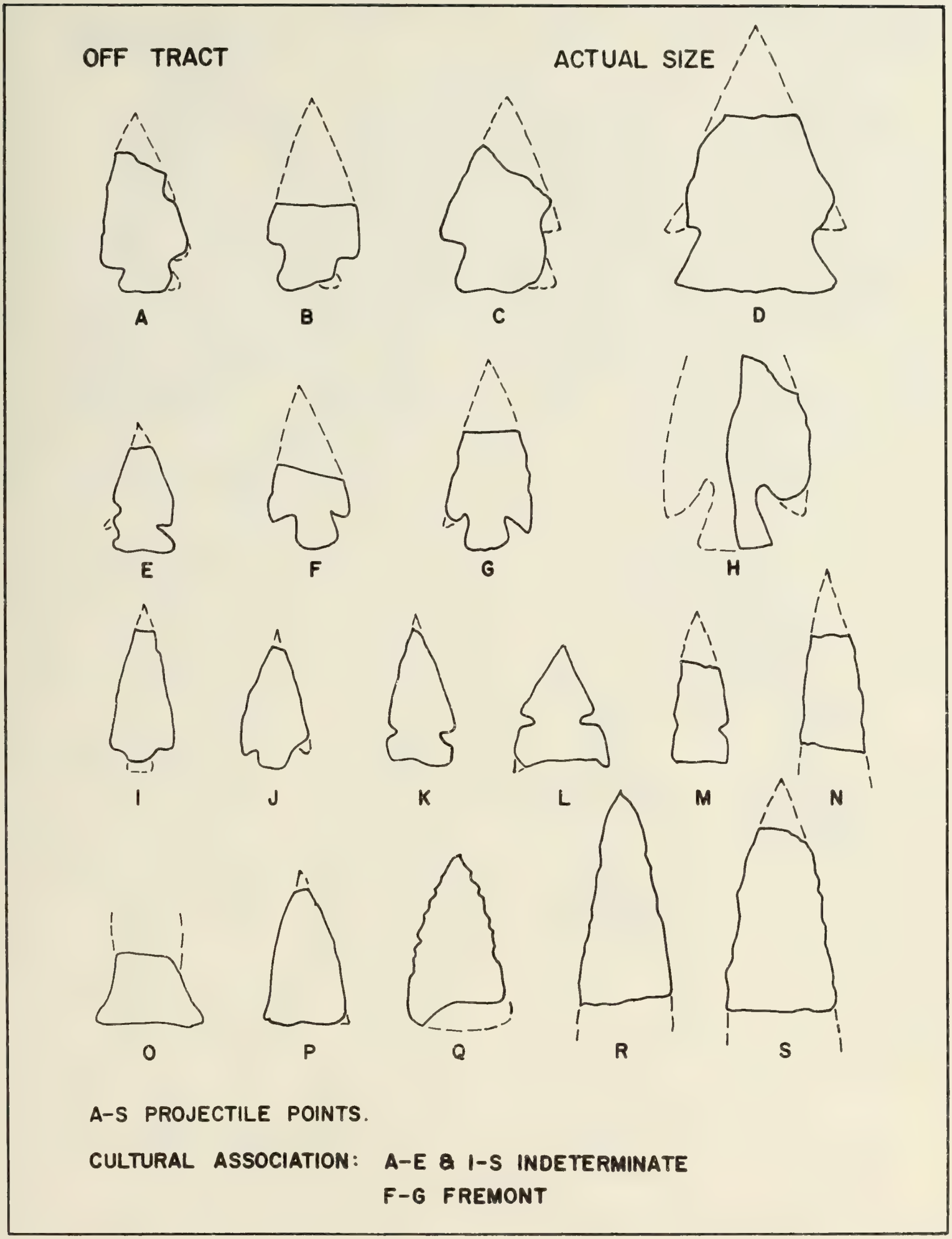

Figure 3-10-5

PROJECTILE POINTS FOUND DURING RBOSP ARCHAEOLOGICAL SURVEY

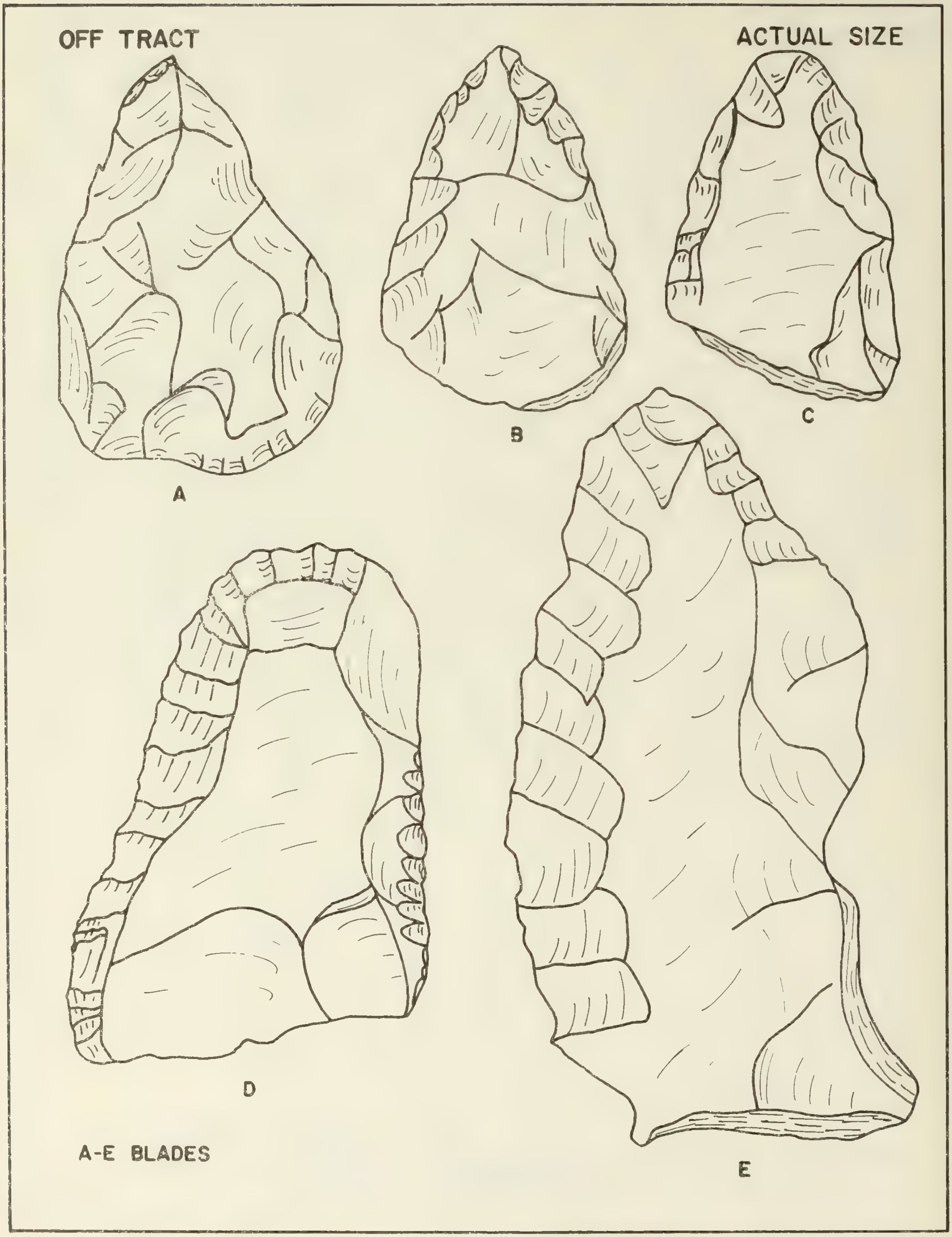

Figure 3-10-6
BLADES FOUND DURING RBOSP ARCHAEOLOGY SURVEY

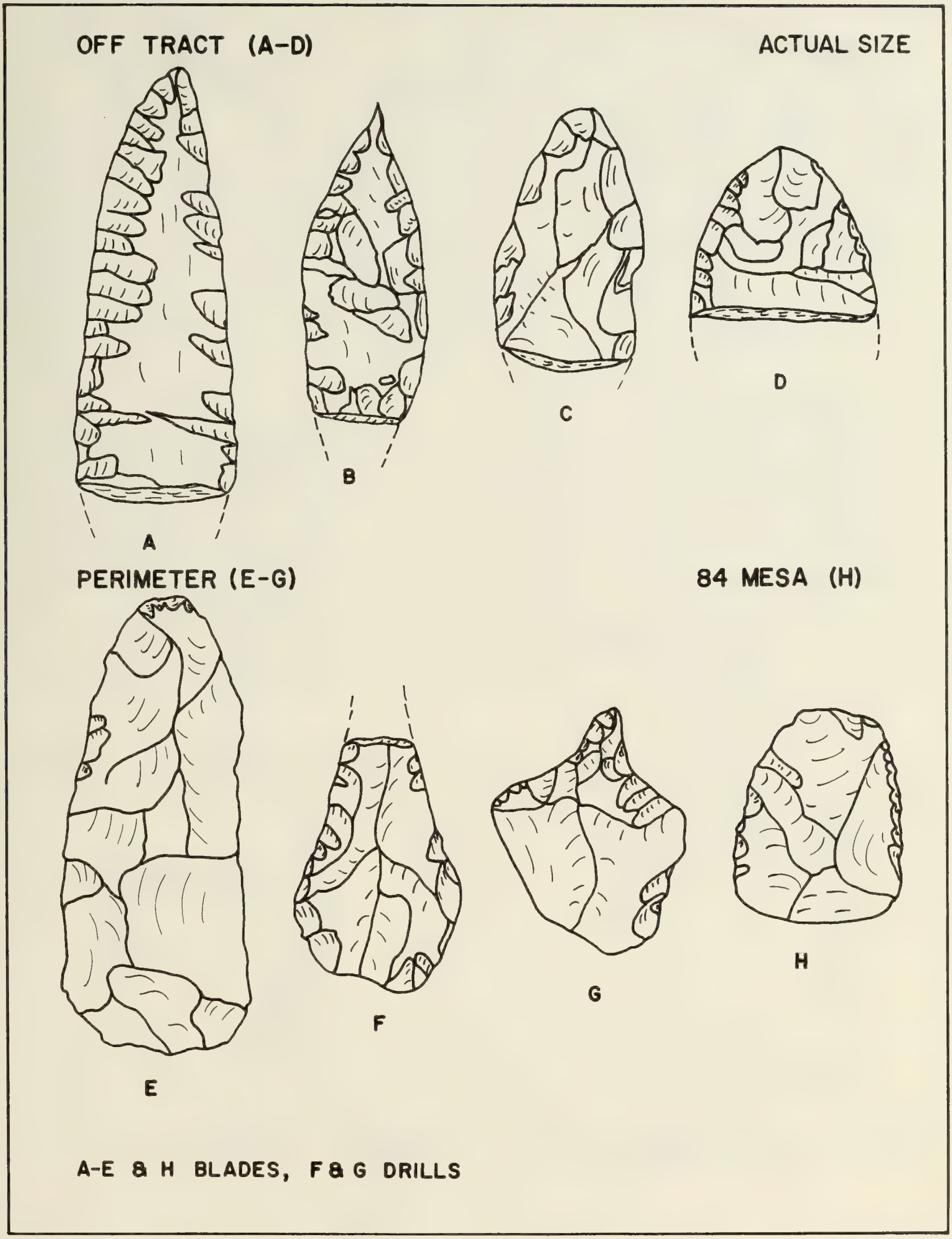

Figure 3-10-7

BLADES & DRILLS FOUND DURING RBOSP ARCHAEOLOGICAL SURVEY

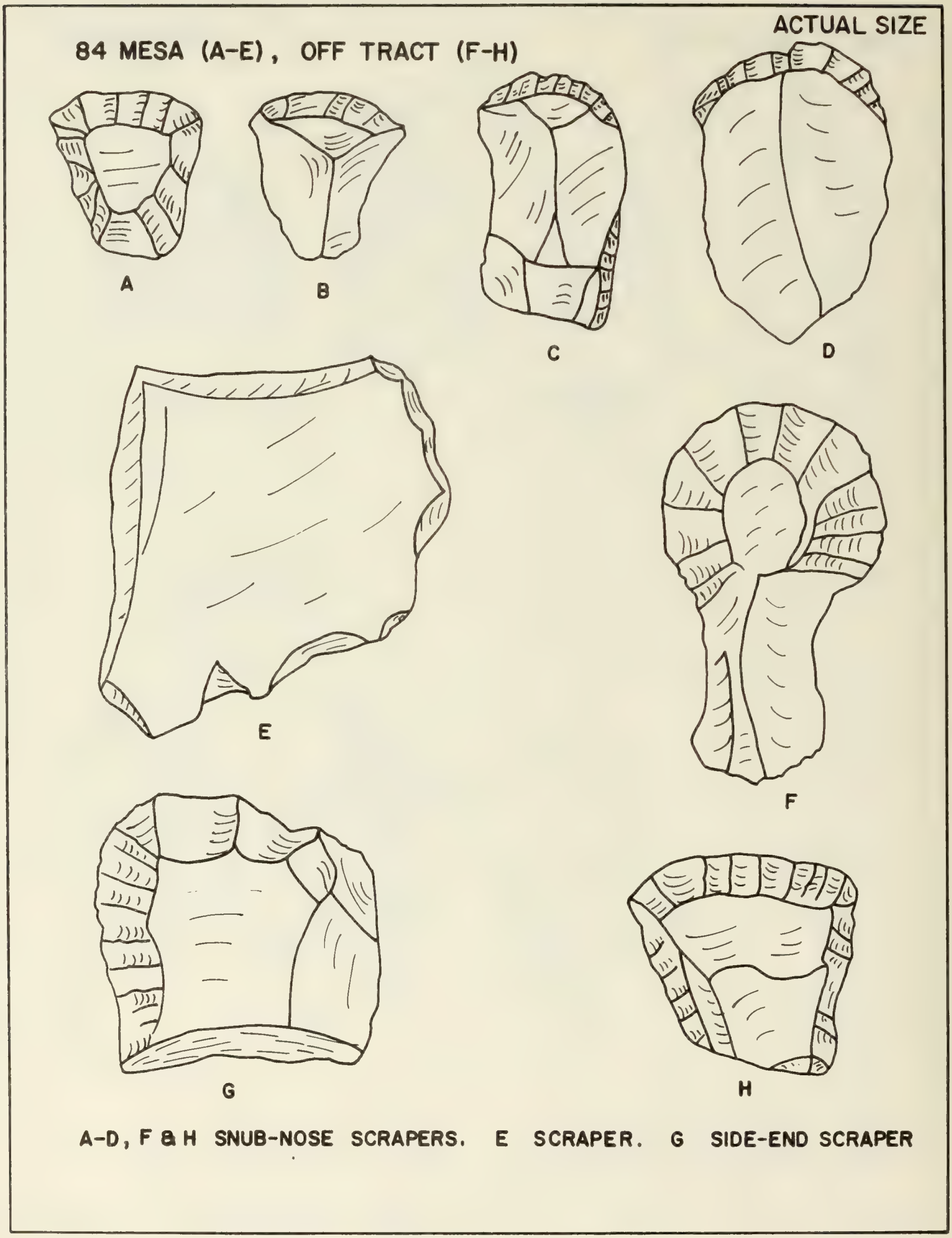

Figure 3-10-8

SCRAPERS FOUND DURING RBOSP ARCHAEOLOGY SURVEY

used in butchering, coarse fabrication, or working non-stone material) and small, pointed etching stones called gravers were included in the collection.

Some broken pieces of pottery were found. The origin of the pottery is not clear. It could have been made locally, but its scarcity suggests that it was brought into the region. Most of the pottery found was undecorated, gray ware similar to that found to the west in Utah and northwest in Dinosaur National Monument. Two small pieces of black-on-white pottery similar to types manufactured in the Mesa Verde region were found, but they are too small to allow absolute identification.

Concentrations of tool wastage and artifacts in open areas were defined as lithic scatters. These represent occupancy long enough to produce, lose, or discard the materials found. These areas may have been used intensively during a short period of time or may represent a camp that was repeatedly used over a period of years. None of the sites found appeared to have been year-round camps. They were instead gathering places for utilization of a particular resource. The aboriginal occupation of Tract C-a and the surrounding Piceance Basin was probably seasonal (fall and summer).

The list of artifacts and site locations for Tract C-a is shown in Table 10-3-1. The 1-mile perimeter sites appear on Table 10-3-2. Artifacts recovered from 84 Mesa are listed on Table 10-3-3 and off-tract sites are shown on Table 10-3-4.

10.5 CONCLUSIONS

The archaeological importance of the Piceance Basin, and of the survey area in particular, stems from the fact that relatively no exploration has been done there. The impending development of the area makes immediate archaeological exploration important. From evidence gathered during the survey, however, it is not considered a "rich archaeological find".

The Piceance Basin was probably not used during the winter because of inclement

TABLE 3-10-1

FIELD SITE NUMBER, SITE LOCATION, AND MATERIAL CULTURE ANALYSIS FOR TRACT C-a ARCHAEOLOGICAL SURVEY.

Field Number	Township	Range	Section			Tool Type: Point	Knife	Scraper	Flakes	Other	Site Classification	Cultural Affiliation
4	T2S,	R99W	S3 ,	SE¼	NW¼		1f		3	Metate	T	-
5	T1S,	R99W	S34,	SW¼	NE¼		1f				T	-
6	T1S,	R99W	S33,	NE¼	SW¼	1f	1f				T	-
7	T2S,	R99W	S4 ,	NW¼	NE¼		1f	6	9		S	I
8	T1S,	R99W	S34,	NW¼	SW¼				3		T	-
9	T1S,	R99W	S33,	NW¼	SW¼				3		T	-
14	T2S,	R99W	S4 ,	NE¼	SW¼			1			T	-
15	T1S,	R99W	S34,	SE¼	SW¼	1f		1	6		T	-
16	T1S,	R99W	S34,	SW¼	SW¼	1f		1	2		T	-
29	T2S,	R99W	S4 ,	NW¼	SW¼					Tool fragment	T	-
33	T1S,	R99W	S33,	SE¼	SW¼			1f			T	-
34	T1S,	R99W	S33,	SW¼	NE¼			1f			T	-
37	T2S,	R99W	S10,	NW¼	SW¼	1f					T	-
38	T2S,	R99W	S9 ,	NW¼	NE¼				1		T	-
39	T2S,	R99W	S10,	SW¼	SW¼				2		T	-
40	T2S,	R99W	S10,	NW¼	NE¼				1		T	-
41	T2S,	R99W	S3 ,	SE¼	SE¼	1	3f		8		T	-
42	T2S,	R99W	S3 ,	SW¼	SE¼					Metate F	T	-
43	T2S,	R99W	S9 ,	NE¼	NW¼				1	Mano fragment		
									1	Tool fragment	T	-
45	T1S,	R99W	S33,	NE¼	SE¼	3f	1f		30		S	I
51	T2S,	R99W	S10,	SE¼	SE¼			1f			T	-
54	T2S,	R99W	S5 ,	SW¼	SW¼				5		T	-

f = Identifiable fragmentary tool

T = Tertiary sites

I = Indeterminant cultural affiliations

TABLE 3-10-2

FIELD SITE NUMBER, SITE LOCATION AND MATERIAL CULTURE ANALYSIS FOR ARCHAEOLOGICAL SITES LOCATED WITHIN 1-MILE PERIMETER OF TRACT C-a.

				Tool Type						
Field Number	Township	Range	Section	Point	Knife	Scraper	Flakes	Other	Site Classification	Cultural Affiliation
10	T1S,	R99W	S29, NW¼ SW¼			1f			T	-
11	T1S,	R99W	S29, SW¼ SW¼	1f			2		T	-
12	T1S,	R99W	S29, SW¼ SE¼				4	Graver	T	-
13	T1S,	R99W	S29, SE¼ SE¼		1f	1	1		T	-
20	T2S,	R99W	S14, NW¼ NW¼	2-4f	2f	3-4f	94	Hammerstone, drill(f)	P	F(?)
21	T2S,	R99W	S15, SW¼ NE¼		1		13		T	-
25	T1S,	R99W	S27, SW¼ SE¼			2	7		T	-
28	T2S,	R99W	S8 , SW¼ SW¼				1		T	-
30	T2S,	R99W	S17, SE¼ SE¼	1f		2	19		T	-
32	T1S,	R99W	S27, NE¼ SW¼			1f	15	1 Tooth fragment	T	-
35	T2S,	R99W	S11, SW¼ NE¼				2		T	-
36	T2S,	R99W	S11, NE¼ SE¼	1f	1	3f	20		S	I
44	T2S,	R99W	S17, SW¼ NW¼	1			1		T	-
47	T1S,	R99W	S35, NE¼ NW¼		1f		22		T	-
50	T2S,	R99W	S16, NE¼ NE¼				2		T	-
52	T2S,	R99W	S15, SW¼ NE¼		1 Historic		5		T	-
53	T2S,	R99W	S6 , SW¼ NE¼		1			1 Toolstone	T	-
55	T2S,	R99W	S15, SE¼ NE¼	2f	1f		4	Toolstone	T	-
56	T2S,	R99W	S6 , SW¼ SE¼				1		T	-
64	T2S,	R99W	S14, NW¼ SE¼	2f	2f	1		Mano, fossil bones, core	S	F(?)
65	T2S,	R99W	S14, NE¼ NE¼	1				Hammerstone		
				3f	1	1f	107	Mano fragment	P	F(?)
66	T2S,	R99W	S14, NE¼ NW¼	1f		3f	25		S	I
67	T2S,	R99W	S11, SW¼ SE¼			1f	10	Hammerstone	T	-
70	T2S,	R99W	S11, SE¼ NE¼				1		T	-
71	T2S,	R99W	S11, NW¼ NW¼			1f	8		T	-
72	T2S,	R99W	S2 , NE¼ SW¼				1			
81	T2S,	R99W	S2 , NE¼ NE¼	1					T	-
				2f			2	Core	T	-
82	T1S,	R99W	S35, SW¼ SW¼				2	Mano fragment	T	-
83	T1S,	R99W	S35, SW¼ SW¼					Mano	T	-
84	T1S,	R99W	S35, NW¼ SE¼	2f	1	2f	22	1 Mano fragments, core	S	I

Table 3-10-2 (Continued)

Field Number	Township	Range	Section			Tool Type: Point	Knife	Scraper	Flakes	Other	Site Classification	Cultural Affiliation
94	T1S,	R99W	S29,	NW¼	SW¼	1f	1f	3	14		S	I
95	T1S,	R99W	S28,	SW¼	NE¼	1f			2		T	-
97	T1S,	R99W	S30,	NE¼	NW¼					Toolstone	T	-
103	T1S,	R99W	S30,	SE¼	SE¼				3		T	-
104	T1S,	R99W	S31,	SW¼	NW¼					Toolstone	T	-
113	T1S,	R98W	S30,	SW¼	SW¼	1f	1	2	5	Mano (f)	T	-
197	T1S,	R99W	S29	NE¼	NE¼					Historic Horse Trap	S	A

f = Identifiable fragmentary tool

P = Primary site

S = Secondary site

T = Tertiary site

- = Cultural affiliation not attempted because of small number of artifacts

I = Indeterminate

F = Fremont

A = Anglo

TABLE 3-10-3

FIELD SITE NUMBER, SITE LOCATION, AND MATERIAL CULTURE ANALYSIS FOR ARCHAEOLOGICAL SITES ON 84 MESA, RBOSP.

Field Number	Township	Range	Section	Tool Type: Point	Knife	Scraper	Flakes	Other	Site Classification	Cultural Affiliation
1	T1S,	R98W	S29, SE¼ NW¼		2f	1 1f	7		T	-
2	T1S,	R99W	S25, SE¼ NE¼	1	1f		3	Basin Metate (#2)	T	-
3	T1S,	R99W	S36, NW¼ SW¼	1f	1f		5		T	-
17	T1S,	R98W	S18, SE¼ SW¼	1f	3f	3f	6		S	I
18	T1S,	R98W	S18, SE¼ SW¼	1 2f	1f	1f	104	Chopper (f)	P	F(?)
22	T1S,	R98W	S18, SE¼ SW¼				9		T	-
23	T1S,	R98W	S30, NW¼ NE¼	3 7f	1 6f	15	178	Hammerstone, drill, 3 choppers	P	F
24	T1S,	R99W	S25, NW¼ SE¼	1f		4f	97	Mano fragments	P	F(?)
26	T1S,	R98W	S20, NW¼ SW¼	1	2f	2f	1		T	-
27	T1S,	R98W	S30, SE¼ NE¼	1 11f	9	16	177	Potsherds, drill F cores, blades, Manos	P	A-F
31	T1S,	R98W	S30, SE¼ NW¼	2	1				T	-
46	T1S,	R98W	S8 , SW¼ SW¼	1f	1f		15	1 historic knife, hammerstone, 5 Mano fragments, chopper, core, trade beads, wickiup structure	P	U
48	T1S,	R98W	S19, SE¼ NW¼	1			2		T	-
49	T1S,	R98W	S19, NW¼ SE¼	1f			3		T	-
57	T1S,	R98W	S19, NE¼ SE¼	2f	3	5	63	Drill (f), pottery	P	F
58	T1S,	R98W	S20, SW¼ NW¼				3	1 potsherd	T	-
59	T1S,	R98W	S20, SE¼ NW¼					Mano fragment	T	-
60	T1S,	R98W	S19, NE¼ SE¼					Mano fragment	T	-
61	T1S,	R98W	S19, NE¼ SE¼					Mano	T	-
62	T1S,	R98W	S19, SE¼ SE¼			1f	2		T	-
63	T1S,	R98W	S20, NE¼ NW¼				2		T	-
68	T1S,	R98W	S8 , SW¼ SE¼		1	2f	9		T	-
69	T1S,	R98W	S17, NW¼ NE¼				1		T	-

Table 3-10-3 (Continued)

Field Number	Township	Range	Section	Tool Type: Point	Knife	Scraper	Flakes	Other	Site Classification	Cultural Affiliation
73	T1S,	R98W	S18, NE¼ SE¼	1f			2	Mano	T	-
74	T1S,	R98W	S18, NE¼ SE¼	1f		3	7	2 Mano fragments, chopper	S	I
75	T1S,	R98W	S18, NE¼ SE¼				3		T	-
76	T1S,	R98W	S17, NW¼ SW¼			1f			T	-
77	T1S,	R98W	S18, SE¼ SE¼					Toolstone	T	-
80	T1S,	R99W	S13, SW¼ SE¼	1f	1f	4	25	Mano fragment, toolstone	S	I
85	T1S,	R99W	S13, SW¼ SE¼		3f	4f	99		P	I
86	T1S,	R99W	S13, NE¼ SE¼	1f	3f 4	1 2f	71	Toolstone, pottery	P	F
87	T1S,	R98W	S30, NW¼ NE¼	1f			36	Toolstone	T	-
88	T1S,	R98W	S30, NW¼ NW¼		1f	2		Mano	T	-
90	T1S,	R99W	S36, NE¼ SW¼	1	3f	1	22	Mano	S	I
91	T1S,	R99W	S11, SE¼ SW¼				1		T	-
92	T1S,	R98W	S8 , NW¼ SE¼			1	2		T	-
93	T1S,	R98W	S7 , SW¼ SW¼					Wickiup structure toolstone	P	U
105	T1S,	R99W	S14, SE¼ SE¼			1f	1		T	-
106	T1S,	R98W	S29, SW¼ NW¼			1f	1		T	-
107	T1S,	R99W	S36, SE¼ NW¼		1f	1f	14		T	-
108	T1S,	R99W	S14, SE¼ SE¼				4		T	-
110	T1S,	R99W	S25, NE¼ SE¼			1			T	-
111	T1S,	R98W	S30, SE¼ SW¼	2		6	103	Drill fragment, Mano fragments, toolstone	P	I
112	T1S,	R98W	S30, SW¼ SE¼				2		T	-
114	T1S,	R98W	S20, SE¼ SE¼				6		T	-
115	T1S,	R98W	S20, SE¼ SE¼	1f	1	6	135	Bone, Mano tool-stone, pottery	P	F
116	T1S,	R98W	S20, SW¼ NE¼	2		1	13	Mano, toolstone	S	F(?)
117	T1S,	R98W	S29, NE¼ NW¼		2	2	9	Mano fragment	T	-
118	T1S,	R98W	S7 , NE¼ NE¼		4f	1f	25	1 Mano fragment	S	I
119	T1S,	R99W	S13, SW¼ NE¼	1f			11	Toolstone	T	-
120	T1S,	R99W	S11, SE¼ NE¼				2		T	-
121	T1S,	R99W	S2 , SW¼ SE¼					Mano fragment	T	-
122	T1S,	R99W	S12, NE¼ NW¼			1f	6		T	-

Table 3-10-3 (Continued)

Field Number	Township	Range	Section		Tool Type: Point	Knife	Scraper	Flakes	Other	Site Classification	Cultural Affiliation
123	T1S,	R99W	S11, SW¼	NE¼			4	17	Core, 2 Mano fragments, toolstone, bone	S	I
124	T1S,	R99W	S10, SE¼	SW¼	1			74		S	I
125	T1S,	R98W	S19, SW¼	SE¼			1	8		T	-
126	T1S,	R99W	S15, SE¼	NE¼				1		T	-
127	T1S,	R99W	S11, SW¼	SW¼			1	2		T	-
128	T1S,	R99W	S15, NW¼	NE¼			1 1f	13	1 Mano fragment, 1 hammerstone, toolstone	T	-
143	T1S,	R98W	S18, NW¼	SW¼			1f	1		T	
109	T1S,	R99W	S36, NE¼	NE¼	1	1	2	82	Mano	S	F(?)

f = Identifiable fragmentary tool

P = Primary

S = Secondary

T = Tertiary

- = Cultural affiliation not attempted because of small number of artifacts

I = Indeterminate

A = Archaic

F = Fremont

U = Historic Ute

TABLE 3-10-4

FIELD SITE NUMBER, SITE LOCATION AND MATERIAL CULTURE ANALYSIS FOR OFF-TRACT ARCHAEOLOGICAL SITES.

				Tool Type					
Field Number	Township	Range	Section	Point	Knife	Scraper	Flakes	Other	Site Classification
19	T2S,	R99W	S13, SW¼ NW¼	2f	1				
					1f	1f	18	Hammerstone	S
78	T1S,	R98W	S21, NW¼ NW¼	1f		1f	5		T
79	T1S,	R98W	S16, SE¼ SW¼			1f			T
89	T2S,	R100W	S13, SE¼ NE¼		1f				T
96	T1S,	R98W	S9 , NE¼ SW¼					Mano fragment	T
98	T1S,	R98W	S5 , SE¼ SE¼				1	Maul	T
99	T1S,	R98W	S9 , NW¼ NW¼					Mano fragment	T
100	T1S,	R99W	S21, SE¼ SW¼				5	Mano fragment	T
101	T1S,	R99W	S21, NW¼ SE¼	1					T
102	T1S,	R99W	S21, NE¼ NW¼			1f			T
129	T1S,	R98W	S32, NW¼ NE¼	5f	1f	3f	88		P
130	T1S,	R98W	S9 , NE¼ SE¼					1 Mano in 2 fragments	T
131	T1S,	R98W	S9 , SE¼ SE¼					1 Mano fragment	T
132	T1S,	R98W	S9 , SE¼ SE¼		1f	1f	14		T
133	T1S,	R98W	S10, SW¼ SW¼					Mano fragment	T
134	T1S,	R98W	S9 , SE¼ SW¼				5		T
135	T1S,	R98W	S21, NE¼ SW¼				1		T
136	T1S,	R98W	S22, NW¼ NW¼				1		T
137	T1S,	R98W	S22, NE¼ NW¼	1f				Toolstone fragment	T
138	T1S,	R98W	S21, SW¼ SW¼	1f	1f		2	Mano fragment	T
139	T1S,	R98W	S10, SW¼ SE¼		1f	1	49		S
140	T1S,	R98W	S9 , NE¼ NW¼	3f	3f	4			
						1f	90	Drill, 5 tool fragments, Mano, 4 Mano fragments, toolstone	P
141	T1S,	R98W	S9 , NW¼ NE¼	1f	1f	2	7		T
142	T1S,	R98W	S10, NW¼ NW¼			1	1	3 potsherds, core, hammerstone, Mano, 10 Mano fragments	S
144	T1S,	R98W	S10, NW¼ NE¼	1f	1f	3f	28	Mano fragment, wickiup	P
145	T1S,	R98W	S10, NW¼ SW¼	1f		5f	14		S

Table 3-10-4 (Continued)

Field Number	Township	Range	Section	Point	Knife	Scraper	Flakes	Other	Site Classification
				Tool Type					
146	T1S,	R98W	S10, SE¼ NE¼	1f	1f	1	35	Chopper, 3 Mano (f), 2 wickiups, 13 small blue trade beads, 2 small white trade beads, 1 blue bead	P
147	T1S,	R98W	S10, SE¼ NE¼		1f	3			
						4f	22		S
148	T1S,	R98W	S11, NW¼ NW¼	2f	2f		52	1 gray sandstone bead	S
149	T2S,	R98W	S4 , SW¼ SW¼			1	3	1 potsherd	T
150	T1S,	R98W	S32, NE¼ SE¼			1f	6		T
151	T1S,	R98W	S33, SW¼ SE¼	2f	1f	4f	42		S
152	T1S,	R98W	S11, NW¼ SE¼	1		1	13	Mano, hammerstone, 1 hammerstone fragment	T
153	T1S,	R98W	S11, NE¼ NE¼	1f	4f	6	51	Mano fragment	P
154	T1S,	R98W	S2 , SW¼ SW¼	1		1			
				2f	1f	1f	89		S
155	T1S,	R98W	S2 , SW¼ SW¼				5		T
156	T1S,	R98W	S2 , SW¼ SW¼				3	Mano fragment petrified bone	T
157	T1S,	R98W	S2 , NE¼ SW¼				20	Petrified bone	T
158	T1S,	R98W	S21, SW¼ NW¼				6	Petrified bone	T
159	T1S,	R98W	S11, NW¼ NW¼			4	9	Hammerstone, 2 Mano	
						2f		fragments	S
160	T1S,	R98W	S16, NE¼ NE¼	3f	4f	1f	43	1 potsherd, 3 Mano fragments	P
161	T1S,	R98W	S16, SW¼ NE¼		1f		4		T
162	T1S,	R98W	S34, NW¼					Mano fragment	T
163	T1S,	R98W	S33, NE¼ NE¼		1f		2	Mano fragment	T
164	T1S,	R98W	S8 , NE¼ NE¼	2f	3f	1f	12	Hammerstone, 4 Mano	
			S9 , NW¼ NW¼					fragments, chopper	S
165	T1S,	R98W	S16, SE¼ SE¼	2f	1f		6	Core	T
166	T1S,	R98W	S1 , SW¼ NW¼		1	1	10	Mano, hammerstone	T
167	T1S,	R98W	S35, NW¼ SW¼	1f	1f		3	Core, Mano fragment	T
168	T2S,	R98W	S2 , SE¼ SE¼	1f			3		T

Table 3-10-4 (Continued)

Field Number	Township	Range	Section			Tool Type: Point	Knife	Scraper	Flakes	Other	Site Classification
169	T1S,	R97W	S19,	SW¼	SW¼				2	Mano fragment	T
170	T1S,	R97W	S18,	SE¼	NW¼				1		T
171	T1S,	R98W	S29,	NE¼	NE¼				3		T
172	T1S,	R98W	S28,	NW¼	NW¼				3		T
173	T2S,	R98W	S6 ,	NW¼	NW¼			1,2f	5		T
174	T1S,	R98W	S31,	SW¼					8		T
175	T1S,	R98W	S31,	NW¼	NE¼	3f	1f	2f	34	Mano, Mano fragment, 5 tool fragments	P
176	T1S,	R98W	S31,	NE¼	NE¼		1f	1	7	Core	T
177	T1S,	R98W	S32,	NW¼	NW¼	4f	2f	2	74	Core tool	P
178	T2S,	R98W	S6 ,	NE¼	NE¼	1f		1			T
179	T1S,	R98W	S32,	NW¼	SW¼	1f			3	Tool fragment	T
180	T1S,	R98W	S31,	NW¼	SE¼	1f			2	Tool fragment	T
181	T1S,	R98W	S32,	SW¼	NE¼		2f		11	Tool fragment	T
182	T1S,	R98W	S31,	SE¼	SE¼		1f		42		T
183	T2S,	R99W	S14,	NE¼	SW¼					Tool fragment	T
184	T2S,	R99W	S23,	NE¼	SW¼				1	Tool fragment	T
185	T2S,	R98W	S19,	NW¼	SW¼				1	Tool fragment	T
186	T1S,	R98W	S1 ,	NW¼	NE¼	3f	1f	4f	40	Hammerstone, Mano fragment, 3 tool fragments	P
187	T1N,	R98W	S36,	E½				1f	7	Hammerstone, Mano	T
188	T1N,	R98W	S24,	SE¼	SE¼	1f	1f	2	15	5 tool fragments, hammerstone	S
189	T2S,	R98W	S3 ,	NW¼		1f	1f	1	42	2 tool fragments	S
190	T2S,	R98W	S4 ,	SE¼	NE¼	1f	2f	3	42	2 toolstone fragments	S
191	T2S,	R98W	S3 ,	NE¼	NW¼	1 1f		1f	11	1 Mano fragment, 2 tool fragments	S
192	T1N,	R98W	S23,	NW¼	NW¼		1		1		T
193	T1N,	R98W	S24,	NE¼	NW¼	1f		1	16	Tool fragment	T
194	T1N,	R98W	S13,	W½		2f		1	8	1 core tool, 1 hammerstone fragment, 1 Mano fragment	S

Table 3-10-4 (Continued)

Field Number	Township	Range	Section	Tool Type: Point	Knife	Scraper	Flakes	Other	Site Classification
195	T1S,	R98W	S34, SW¼ SE¼	1					T
196	T1N,	R98W	S13, E½		1 1f	2f	4	Mano, Mano fragments, 3 tool fragments, 4 petrified bone fragments	S

f = Identifiable fragmentary tool

P = Primary site

S = Secondary site

T = Tertiary site

[1] = Sites off-tract other than 84 Mesa or the 1-mile perimeter

[2] = Cultural affiliations of off-tract sites are not yet available

weather, nor during spring because of poor hunting. The combination of hunting tools, meat and skin processing tools, and tools used for the preparation of vegetal materials suggest that the area was occupied from summer through fall. A limited food supply during some seasons probably prevented the large gatherings of people. The types of tools suggest that two patterns of exploitation, interlocked in terms of time, occurred in the area. In late summer and fall, hunting and gathering could have been practiced simultaneously. Hunting was probably performed by men and gathering by women and children except during highly successful seasons when processing of game and gathering may have been shared. The area was primarily used as a source of game and vegetal products. Good harvests of pinyon nuts probably drew people into the area in some instances. Agriculture was probably not practiced in the basin except in lowland areas to the north and east along the major drainages.

Other evidence suggests that hunting was a primary concern, but the killing and butchering of deer or elk leaves very little evidence. Once the animal was butchered, the meat utilized, and the bones discarded, the evidence disappeared through natural processes. For these reasons, no kill sites were found.

Field and laboratory analysis indicate there were at least four periods of occupation of the area: an Archaic period perhaps beginning as early as 7000 to 6000 B. C.; followed by the Fremont Culture that began after 500 A.D.; the Ute, whose beginnings are not presently established; and, finally, the 19th century Anglos.

The socio-political organization was uncomplicated. Exploitation was accomplished most efficiently by the extended family unit (J. Jenning, 1974). They must have possessed considerable knowledge of natural history, seasonal patterns of game movements, and ripening times of various plants, as these were the criteria that dictated the movement of the group. Exploitation patterns indicate that deer, elk, plants, fish, insects, waterfowl, rodents, and reptiles were eaten. Material culture was geared to frequent changes in location. Flexible containers of hide or basketry were used instead of ceramics. Other types of equipment were practical and portable. Clothing

was minimal and housing constructed only when a subsistence item was plentiful enough to support the group in one place for a period of time. Caves or overhangs were used when they occurred. Most artifacts found in the area that can be identified with the Archaic are projectile points. This occupation could extend back several thousand years, but this inference cannot be positively confirmed from surface materials gathered in the survey.

The Fremont Culture, originally defined by Morss (1931), continued the Archaic pattern of subsistence. Agriculture and pottery were diffused into the area from the southwest. There was considerable influence from the Four Corners region. Five subdivisions of that pattern have been identified in Utah and two border the northeastern portion of Colorado. One of the two bordering Colorado, the Uinta area, is located in northeastern Utah and the other, the San Rafael, is in eastern central Utah. The time span for these periods is from approximately 450 to 1400 A. D. These groups revealed less Puebloan contact.

Most artifact material shows a continuation from the Archaic. Projectile points decreased in size and differed in outline, but most tools were not altered. Ornaments and pottery were added and leather footgear and clothing became more common. Clay figurines of men and women have been found in several areas, but not in the Tract C-a area. While agriculture expanded the economic base, hunting and gathering were still most important. Social patterning did not differ significantly from that of the Archaic.

The Meeker region is noted for the Ute massacre at Meeker's trading post. The time and extent of the Ute occupation is less well known. The Ute may well be a continuation out of Fremont with the addition of the horse and items of European manufacture. Several sites were found which had wickiups, or the conical frames for small houses. The shape is tipi-like, with the use of smaller brush and juniper bark as the covering. Some are still standing and show the interlocked main frame elements. Unfortunately, artifacts at these sites were very scarce and do not aid in dating the structures. At one site, a butcher knife was found; however, this could have been lost by Anglos.

Historic material is also present in the vicinity of the tract. It includes the 84 Ranch, the school, several homesteads, a horse trap, and a cabin, now all abandoned. The area is currently leased for cattle raising, and permanent residents are found near Piceance Creek.

10.6 RECOMMENDATIONS

Material collected during the survey discussed herein has not been fully analyzed; therefore, recommendations to the National Register of Historic Places cannot be included as a part of this report. However, information gathered by Jennings (1974) and during the current survey indicates that the presence of eligible sites cannot be ruled out. Analysis is nearing completion. This analysis will include specific site identifications, descriptions of clustered sites, consideration of duplicate finds by Olson and Jennings, precise mapping, and interpretations of significance. This information will fulfill requirements set forth in the Federal Register and Federal Executive Order 11593 for nomination of sites to the National Register of Historic Places. It will be presented to the BLM in a separate report. Sites which qualify for the National Register, if any, should be treated as primary sites and appropriate steps should be taken to insure their protection, either by avoidance or salvage.

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CHAPTER 11

PALEONTOLOGY

11.1 OBJECTIVE

The objective of this chapter is to estimate the potential for a significant paleontologic discovery within or immediately adjacent to Tract C-a during tract development. A significant discovery is here defined as one which is unique to the area or one in which an unusually large concentration of well preserved fossils is located.

11.2 METHOD

Geologists involved in the surface geologic mapping program (structure mapping by plane table and alidade methods, stratigraphic section lithologic descriptions) were constantly on the alert for paleontologic finds. In addition, the other contractors involved in the various baseline data gathering programs in and around Tract C-a were contacted to determine if any significant paleontologic finds were encountered in the course of their field work. These contractors include those charged with archaeological investigations, ecological investigations and the core hole program. A brief literature search was also made.

11.3 DATA SUMMARY

No significant paleontologic finds have been observed on the surface in or around Tract C-a. Geologists involved in the surface geologic mapping program encountered only small plant remains, mainly fragmental, scattered throughout the outcrops of the upper Parachute Creek Member, Green River Formation. Remains of this type are relatively common throughout the Piceance Creek basin. No fossils were observed in the overlying Uinta Formation.

In the subsurface, a review of tract core hole lithologic description logs disclosed the presence of sparse small fish remains below the Blue marker in the Garden Gulch Member in three G-S core holes, Nos. 9, 13 and 15 (see tract cross section, Fig. 3-3-4, Sec. 3, Chap. 3). No other vertebrates were observed in the subsurface. These fish remains are also not unique to Tract C-a. Brobst and Tucker (1973, p. 8-12) located fish remains at the "pipeline" outcrop section on Cathedral Bluffs about five miles southwest of Tract C-a. Cashion (1967, p. 13 & 16) report their presence in the Parachute Creek and Garden Gulch Members in both the Piceance Creek and Uinta basins of Colorado and Utah, respectively.

Also reported by Brobst and Tucker at the "pipeline" section are turtle and insect remains and a catfish skull in oil shales above the Mahogany zone. None of these fossils have been found within or in the immediate vicinity of Tract C-a.

11.4 CONCLUSION

By definition, Green River oil shale contains variable amounts of organic matter derived chiefly from micro-organisms and is therefore inherently fossiliferous. Two kinds of organic matter are distinguishable in thin sections of oil shale (Bradley, 1931, p. 39). One is paleontologically structureless (amorphous) and makes up the vast majority of oil shale's organic fraction. The second consists of complete or fragmentary micro-organisms such as algae, protozoa and insects and parts of higher plants such as spores, pollen grains and minute pieces of tissue. Microfossil remains of these organisms are indigenous to oil shale throughout the basin. Megafossils, such as the previously mentioned turtle and fish remains, are locally present scattered throughout various horizons in the oil shale sequence.

Although a significant paleontologic discovery is always a possibility during any excavation in or adjacent to Tract C-a, that possibility is considered extremely remote based on the data compiled. However, should such a discovery be made, measures will be taken to protect it and the AOSS will be notified in compliance with the lease stipulations (See Section 9, Chapter 12).

11.5 REFERENCES

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CHAPTER 12

SOILS AND OVERBURDEN

SECTION 3

BASELINE CONDITIONS

CHAPTER 12
SOILS AND OVERBURDEN

An inventory of soil types found on Tract C-a and adjacent areas and their physical and chemical characteristics and distribution is required for ecological analysis and engineering studies. Soils data are a basic requirement for understanding the diverse relationships involved between soils, plants, and wildlife. Soils information is also necessary to design a revegetation program. Chemical data from overburden analyses will be used to anticipate possible toxic strata which may cause difficulties in the revegetation program or lead to potential pollution of aquatic systems through leaching action on stockpiles or spent shale disposal sites. Physical and structural testing of soils and overburden are necessary to evaluate their use potential for plant structures, disposal and storage sites, and reservoir construction.

Soils and overburden were arbitrarily separated into two classes for study and analytical purposes. These classes are surface soil (material in upper 1.5 m (5 ft)) and subsurface soil and overburden (material below 1.5 m and approximately 5 m (15 ft) into bedrock or to a maximum depth of 15.25 m (50 ft)).

A limited amount of information on general physical and chemical characteristics of soils and overburden of the oil shale area may be found in reports prepared by Campbell, et al. (1974) and Fox (1974). A general soils map (compiled at a scale of 1:250,000) of the oil shale area in Colorado was prepared by Campbell, et al. (1974). This general soils map combined soils maps of Rio Blanco, Garfield, and Mesa counties which had been published by the Soil Conservation Service, USDA, July 1972.

12.1 MAPPING

A. Objectives - The objectives of the soil survey are to describe and map soil series, depths of the various horizons of soil, strike and dip of the soil, slope, vegetation cover, and erodibility. Mapped soils information is essential before reliable predictions can be made about soil behavior when subjected to various uses. Soils maps will show the geographical extent and areal distribution of soils, allowing evaluation of erosion, sediment yield, runoff, site suitability, etc. The availability and detail of soils maps will be of primary importance for evaluating fertility, water needs, and conservation practices associated with revegetation activities.

B. Methods - A preliminary soils and vegetation survey of Tract C-a, 84 Mesa, and adjacent areas was conducted in Spring 1975. Several soil pits were excavated concurrent with soil coring to determine soil series and their distribution. Data from the survey were used to produce a preliminary map (Figure 3-12-1) of soil series distribution on Tract C-a and adjacent areas. More detailed information on the distribution of the various soil types, depths, zonation, number, width of horizons, and physical and chemical characteristics is being prepared and correlated with the type and success of vegetation in the area. Soil profiles of the area are being determined by field sampling from soil pits and by study of soil profiles exposed along road cuts and erosion faces. One soil sample site is associated with each of the 35 permanent vegetation sampling plots and at least one soil pit associated with each of the 11 major soil series.

C. Data Summary - The preliminary soils map and legend (Figure 3-12-1) prepared by the SCS is currently undergoing further revisions. A general description of the 11 soil series (or associations) and rock outcrops encountered during surveying and mapping by the SCS are discussed in the General Soils Discussion, Section 3-12-4.

12.2 SURFACE SOIL - CHEMICAL AND PHYSICAL PROPERTIES

A. Objectives - The objectives of the soil chemistry study are to depict the amounts of certain major and minor chemical elements in soils of Tract C-a and surrounding areas and to measure the potential of the soils as a source of nutritive elements as well as possible toxic elements. Soil chemistry data are being correlated with phytosociological data and plant distribution to ascertain relationships between plant response and soil chemical characteristics. Physical tests of soils are necessary to aid in identifying soils and evaluating erosion potential and moisture-holding capacity of soils that may be used for revegetation.

B. Methods - One soil sample site is associated with each of the 35 permanent vegetation sampling plots established by the terrestrial field consultant. In addition, five soil sampling sites are associated with each of the 11 major soil series.

Surface soil is being collected from each soil horizon or, in the case of nondefinitive horizons, composite soil samples are being collected at intervals from 0 to 10 cm, 10 to 50 cm, 50 to 100 cm, and 100 to 150 cm. In either case, a minimum of four soil samples per sample site are being collected.

Composite soil samples have already been taken using a 5 cm (2 in) diameter split spoon sampler at 45 cm (1.5 ft) increments down to 135 cm (4.5 ft). These samples, supplementing the surface soil sampling program, were taken from the various areas to be impacted by the mining operation. These additional sites sampled included the on-site open pit mine areas and the proposed water control damsite area. These supplemental samples are currently undergoing chemical analysis.

Each of the soil samples are being subjected individually for the laboratory analyses indicated below. Most procedures of chemical and physical analyses follow methods discussed by Black et al. (1965).

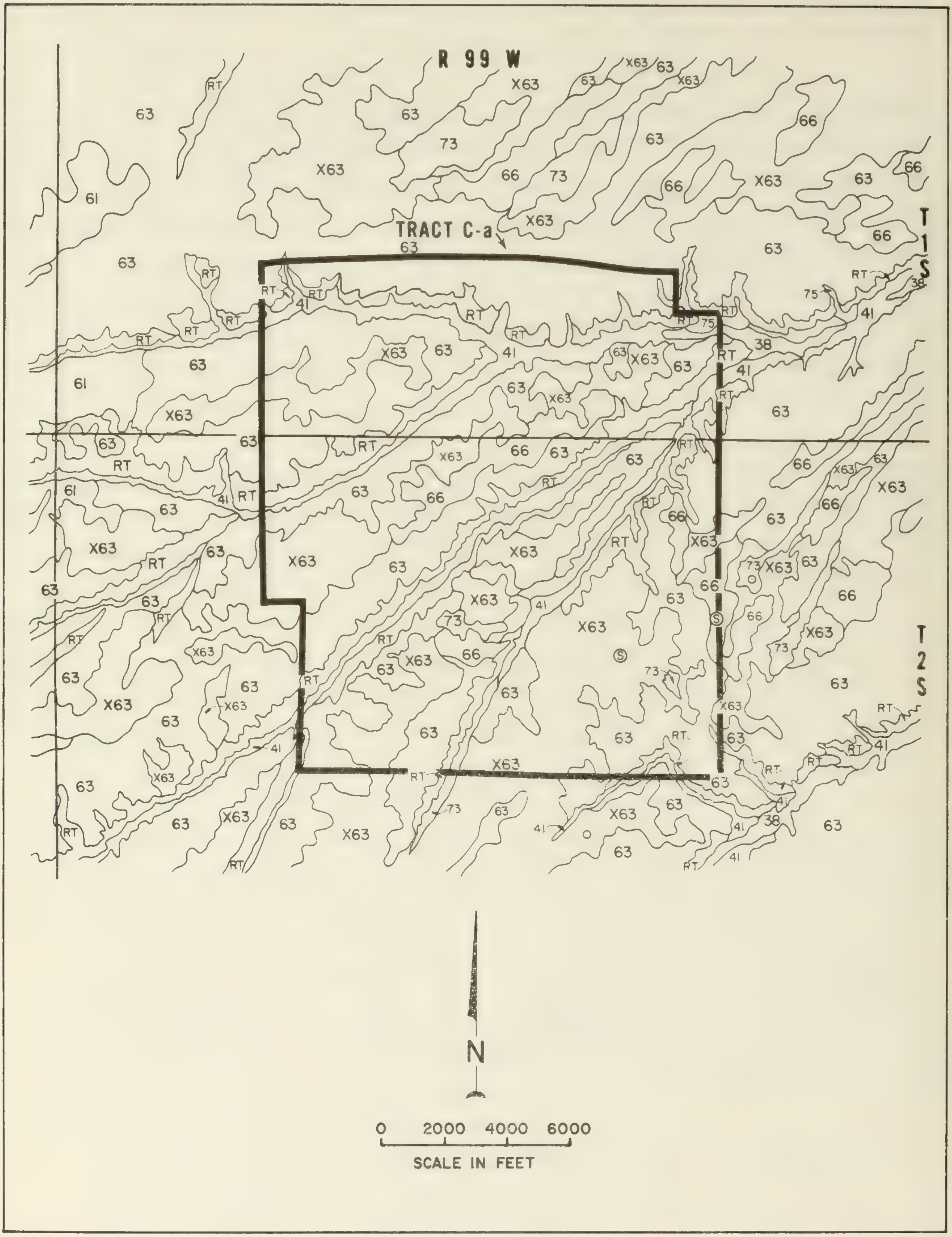

Figure 3-12-1

SOILS MAP OF TRACT C-a

Figure 3-12-1 Preliminary soils map of Tract C-a and adjacent areas (prepared by Soil Conservation Service, October 1975).

Map Symbol	Unit Name
60	Aridic Haploborolls, fine loamy mixed, 12 to 50 percent slopes
71C	Forelle loam, 3 to 8 percent slopes
71D	Forelle loam, 8 to 15 percent slopes
41	Glendive fine sandy loam, 2 to 9 percent slopes
9	Hagga loam, 0 to 5 percent slopes
75	Hanly gravelly loamy fine sand, 2 to 9 percent slopes
38	Havre loam, 0 to 3 percent slopes
38C	Havre loam, 3 to 8 percent slopes
61	Lithic Haploborolls, loamy skeletal mixed, 15 to 50 percent slopes
70	Piceance fine sandy loam, 5 to 15 percent slopes
66	Redcreek-Rentsac complex, 5 to 30 percent slopes
63	Rentsac channery fine sandy loam, 5 to 50 percent slopes
X63	Rentsac-Piceance complex, 0 to 25 percent slopes
RT	Rock Outcrop-Torriorthents, 15 to 90 percent slopes
73	Yamac loam, 2 to 15 percent slopes

Chemical Analysis

pH water
pH $CaCl_2$
Conductivity
Cation Exchange Capacity
Lime
Gypsum
Organic Matter
As
Cd
Cl
Cr
Co
F
Hg
Mo
NH_4
NO_3
Sb
Se
V

$NaHCO_3$ Extractable P
Total P

Water Soluble:
- B
- Ca
- K
- Mg
- Na
- SO_4

NH_4Ac Extractable:
- K
- Na
- Ni
- Pb

DTPA Extractable:
- Cu
- Fe
- Mn
- Zn

Background Radioactivity As:
- Uranium
- Equivalent Uranium
- Equivalent Thorium
- Potassium Radioactivity

Physical Analysis

Particle size distribution and classification
Soil moisture release curves - relationship between soil water potential and percent moisture

C. Data Summary - Samples are being analyzed and results and reports will be submitted to the AOSS upon completion of the various programs (end of second quarter of 1976).

12.3 SUBSURFACE SOIL AND OVERBURDEN - CHEMICAL AND PHYSICAL PROPERTIES

A. Objectives - There are several objectives of the subsurface soil and overburden testing program. Physical and structural testing objectives are to evaluate use potential of soil and overburden for plant structures, disposal and storage sites, and reservoir construction. The chemical analysis objective is to ascertain potentially toxic materials that may limit

rehabilitation efforts and/or contribute potentially toxic materials (especially trace metals) to surface and ground water systems. The depth test objective is to determine quantity and depth of overburden soil available for rehabilitation.

B. Methods - Drill hole information has been gathered to determine quantity and depth of overburden soil available for rehabilitation. Preliminary settlement characteristics of soils under plant structures and the water quality control reservoir dam are being determined. Bearing capacity of soils and depth to bedrock are being determined in plant areas. In-place permeability of soil and rock under disposal sites and water quality control reservoir and dam sites are being measured to use in estimating seepage and groundwater pollution potential.

1. Drilling and Sampling - Drilling and sampling of overburden soils extended through soil overburden and approximately 5 m (15 ft) into bedrock or to a total depth not exceeding 15 m (50 ft), whichever was less. The number, location, and estimated depth of the bore holes are presented in Table 3-12-1. A hollow flight auger with an outside diameter of 15 to 20 cm (6 to 8 in) was used in overburden soil. Core drilling techniques were used to extend the hole approximately 5 m (15 ft) into bedrock except in the water quality control reservoir area where holes were drilled deeper for engineering design. The three drill holes recommended along the proposed axis of the water quality control dam were drilled to approximately 23 m (75 ft). All bedrock was cored and water pressure tests were made in bedrock to determine dam foundation permeability. The number of holes shown in Table 3-12-1 were considered to be the minimum number necessary to obtain soil information. However, they are not considered sufficient to determine the volume of overburden soil available for rehabilitation. A seismic survey will supplement the drilling program in this respect by providing line interpretations of the bedrock-overburden soil contact.

Table 3-12-1

SOIL DRILLING, SAMPLING, AND TESTING -- TRACT C-a

		Mine Area	Plant Site	On-Tract Disposal Area	Off-Tract Disposal Area	Water Control Reservoir	Total
1.	No. of Sites	1	1	1	1	1	5
2.	No. of Holes	2	3	2	5	4	16
3.	Maximum Depth to Bedrock	18	15	70	10	70	--
4.	Footage Includ. 4.5 m (15 ft) of Rock	94	86	122	163	390	855
5.	Std. Penetration Test (1 per 1.5 m (5 ft)	18	9	35	19	55	136
6.	Atterburg Limit Tests	2	3	2	4	4	15
7.	Grain Size Distribution Analysis	2	3	2	5	4	16
8.	Specific Gravity Test	0	3	0	1	2	6
9.	Compaction Test	0	2	0	1	2	5
10.	Unified Soil Classification	2	3	2	5	4	16
11.	One-Dimen. Consolidation*	0	3**	0	3**	2	8
12.	Remolded Perm. Test*	1	1	2	1	3	8
13.	Rock Permeability Test and In-Place Permeability Test on Soil	0	0	3	7	12***	22
14.	Triaxial Shear Test	0	0	0	2*	3*	5
15.	Unconfined Rock Test	0	7	0	0	8	15
16.	Background Radiation	2	2	2	2	2	10

* Remolded soil sample
** Undisturbed soil sample -- shall be large enough to test at four different chamber pressures in triaxial shear test
*** Includes preliminary drill hole rock permeability testing with water under pressure

2. Seismic Survey - Due to the limited number of drill holes, a seismic survey was conducted to supplement the drill hole information to determine the bedrock profile in the water control dam site and the depth of soil available for rehabilitation purposes. Approximately 4,500 m (15,000 ft) of seismic line was laid, coordinating with the drill holes. Line patterns were determined in the field so as to obtain the maximum amount of information.

3. Soil Tests - The following soil testing has been or is being performed at each change of material:

a. Standard Penetration Test - Standard penetration tests, which are used in foundation exploration to indicate relative density and relative consistency of in-place foundation cohesiveness of soils (USDI, 1968), were performed during the drilling and sampling. Following standard drilling practice, one standard penetration test was performed at each change of material but did not exceed 1.5 m (5 ft) intervals in each hole drilled. The first penetration test in each hole was taken at a depth of 1.5 m (5 ft).

b. Atterberg Limits/Consistancy Limits - The liquid and plastic limit, which are indices of the workability of firmness of artificial mixtures of soil and water as affected by the content of water in the mixture (USDI, 1968), was determined in accordance with ASTM Standard Specifications D-423 and D-424. The number, site, and location of the Atterberg limit tests are described in Table 3-12-1.

c. Grain Size Distribution Analysis - A grain size, or particle size, distribution analysis was performed in accordance with ASTM Standard Specification D-422. The number, site, and location of tests performed are shown in Table 3-12-1.

d. Unified Soil Classification - The information obtained in items b and c above are being used to classify the soil samples according to the Unified Soil Classification System.

e. Compaction Test - Compaction tests (soil volume change produced artificially by momentary load application) on soil samples were performed according to ASTM Standard Specification D-698. Moisture density curves were drawn for each test and the maximum dry density and optimum moisture content determined. A zero voids curve is shown on these curves.

f. Specific Gravity Test - Specific gravity tests were made in accordance with ASTM Standard Specification D-854 to determine the specific gravity of the material. The number of samples shown in Table 3-12-1 are considered the maximum number required. Information on specific gravity is being used in the analysis of the one-dimensional consolidation test and calculation of overburden pressures. It is also being used to determine the zero voids curve for the compaction test.

g. One-Dimensional Consolidation Test - Consolidation tests (soil volume change achieved with the passage of time) were performed in accordance with USBR Designation E-15 on soils from locations indicated in Table 3-12-1. These tests allow determination of the expected consolidation of the overburden under given heights of fill. The in-place density was also determined on each sample. The samples were loaded to a maximum pressure approximately equal to 150 m (500 ft) of overburden.

h. Undisturbed Laboratory Permeability Test - Permeability measurements (the rate at which water may penetrate soil) were made in accordance with USBR Designation E-15 on soil samples used for the one-dimensional consolidation test. For these samples, the one-dimensional consolidation test was performed in a fixed-ring consolidometer and permeability measurements determined under soil pressures that approximated overburden heights of 3, 15, 30, and 150 m (10,50,100, and 500 ft). The permeability determined by this test is the vertical permeability of the existing ground.

i. Remolded Laboratory Permeability Test - Soil samples were compacted in the laboratory and tested in accordance with USBR Designation E-13 for permeability. Depending on the characteristics of the soil, either the constant head or falling head permeability test was used.

j. In-Place Soil Permeability Test - Depending on the elevation of the water table, either pumping tests or percolation tests were performed in the overburden soil and bedrock beneath soil cover. These tests define the apparent horizontal permeability of the soil and were conducted according to the USBR Designation 18, Appendix E or Designation 19, Appendix E. Selected holes were tested in the wastewater reservoir and at each of the two disposal areas.

k. Triaxial Shear Test - Shear tests, used to determine the resistance to sliding of one mass of soil against another, were performed on samples obtained from the off-tract disposal area and water control reservoir site. These samples were remolded to determine shear strength of disposed overburden. The information from these tests and the standard penetration test is being used to predict bearing capacity and stability.

l. Chemical Analysis - Chemical analysis, as discussed in Section 3-12.2, is being performed on soil samples. Composite samples from 45 cm (1.5 ft) increments for the upper 135 cm (4.5 ft) and 3m (10 ft) intervals down to bedrock or 15 m (50 ft) are being analyzed.

m. Rock Testing - The borings to obtain soil samples were extended into bedrock using coring methods so that 5 m (15 ft) of useable core was obtained. Deeper core drilling was needed at the wastewater reservoir dam site. The material from the cores obtained in the plant site and wastewater reservoir site were subjected to tests as required to determine the unconfined compressive strength. The cores were logged to determine the fracture and joint pattern at the top of bedrock which may allow water to percolate through bedrock. The intact rock appeared to be relatively impermeable so primary permeability was not the controlling factor. The secondary or fracture permeability was obtained using packer head methods.

C. Data Summary - Field work has been completed and physical and chemical analyses are currently underway. Results and reports will be submitted to the AOSS upon completion of sample analyses (by end of first quarter of 1976).

12.4 GENERAL SOILS DISCUSSION

The following discussion represents interpretations of results obtained from the preliminary soils survey of Tract C-a and adjacent areas. An updated discussion will be generated upon completion of designated programs.

The Aridic Haploboroll, loamy-skeletal, mixed, unnamed series consists of moderately deep, well-drained soils that formed in colluvium on foothill sideslopes. Effective rooting depth is 100 cm (40 in.) or less. Organic matter content in the surface layer is medium. Infiltration is moderate. Available water-holding capacity is moderate, surface runoff is moderate to high, and erosion hazard is moderate. These soils have slopes of 12 to 50%. Mean annual precipitation is about 46 cm (18 in.), and mean annual air temperature is about 5 to 6 C (42 F). This soil generally supports vegetation which is used for summer livestock grazing and mule deer winter habitat. The soil has a severe limitation for sanitary facility uses due to slope (this includes sewage lagoons, septic tank absorption fields, and landfills). Use of these soils for local roads and streets is moderately to severely limited.

Forelle series consist of deep, well-drained soils that formed in calcareous, aeolian (windblown) sediments. Effective rooting depth is 150 cm (60 in.) or more. Infiltration is moderate. Available water-holding capacity is medium, surface runoff is slow, and erosion hazard slight. Forelle soils are on uplands and terraced slopes and have slopes of 3 to 15%. Mean annual precipitation is about 35 to 46 cm (14 to 18 in.), and mean annual air temperature is about 5 to 6 C (42 F). Forelle soil is used in dryland farming. Vegetation supported by this soil is used for livestock grazing and wildlife habitat. It is well suited for community development, sanitary facilities, and recreational areas. This soil is a good source for topsoil and is fair for roadfill material.

Glendive series consist of deep, well-drained soils formed in alluvial materials. Effective rooting depth is 150 cm (60 in.) or more. Organic

matter content in the surface is medium. Infiltration is moderate. Available water-holding capacity is moderate, surface runoff is slow, and erosion hazard slight. Glendive soils are in valley positions and have slopes of 2 to 9%. Mean annual precipitation is about 35 cm (14 in.), and mean annual air temperature is about 6 C (43 F). This soil can be irrigated and the vegetation used to support livestock grazing and wildlife habitat. Rare flooding would limit the use of Glendive soils for community development, sanitary facilities, and recreational areas. This soil is a good source of roadfill material.

Hagga series consist of deep, very poorly drained soils that formed in alluvium derived mainly from calcareous sandstones and shales. Effective rooting depth is 150 cm (60 in.) or more. Organic matter content in the surface layer is medium. Infiltration is moderately slow. Available water-holding capacity is high, surface runoff is very slow with some ponding, and erosion hazard is slight. Hagga soils are on valley bottoms and have slopes of 0 to 5%. Mean annual precipitation is about 40 cm (16 in.), and mean annual temperature is about 7 C (45 F). These soils are chiefly planted to native and seeded grass hay, with limited acreage being seeded to small grain for hay. Yields of the more desirable grasses and small grains are limited by the high water table. In the fall, ducks utilize the grasses on Hagga soils; however, they find most of the seeds on areas of poorly-drained soils which are too wet to mow. In evenings, deer concentrate on Hagga soil for the water which is associated with it. Hagga soils have a poor potential for urban and recreational developments. High water tables are the chief limiting feature, and prevalent surface ponding leads to a mosquito problem. Problems will arise with septic tank absorption fields because of the high water table. Experience with deep borings are too limited to indicate whether vertical leach lines would be feasible.

Hanly series consist of deep, somewhat excessively-drained soils that have formed in detrital alluvium of calcareous sandstone and shale origin. Effective rooting depth is 150 cm (60 in.) or more. Organic matter content is low. Infiltration is rapid. Available water-holding capacity is low, surface runoff

is slow, and erosion hazard is medium. Hanly soils are on alluvial fans and in narrow valleys with slope gradients of 2 to 9%. Mean annual precipitation is about 15 cm (6 in), and mean annual air temperature is about 7 C (45 F). Vegetation produced on the Hanly soil has a fair potential for supporting cottontail and deer. These animals use grasses, forbs, and brush, obtaining their shelter primarily from the brush. As roads are improved in the area, more of this soil will be used as a source of roadfill material. Typically, the top layer has less gravel; thus, this top portion should be put aside rather than mixed in with the more gravelly layers in areas which are mined for roadfill material. If domestic water wells are drilled through these soils, care should be taken that sewage effluent does not leach into the water-bearing strata.

Havre series consist of deep, well-drained soils that formed in calcareous, mixed alluvium. Effective rooting depth is 150 cm (60 in) or more. Organic matter content in the surface is medium. Infiltration is moderate. Available water-holding capacity is high, surface runoff is slow, and erosion hazard is slight. These soils are on floodplains and low terraces and have slopes of 0 to 8%. Mean annual precipitation is about 40 cm (16 in), and the mean annual air temperature is about 6 to 7 C (44 F). Havre soils are planted to pasture and the vegetation supports livestock grazing and wildlife habitat. These soils have moderate limitations for sanitary facilities and severe limitations for community development and recreational areas because of the flood hazard. Havre soils are fair sources for roadfill material due to low strength and moderate shrink-swell. It is a good source for topsoil.

The Lithic Haploboroll, loamy-skeletal, mixed, unnamed series consists of shallow, well-drained soils that formed in sandstone residuum on upland slopes and ridge tops. Effective rooting depth is 50 cm (20 in) or less. Organic matter content in the surface layer is medium. Infiltration is moderate. Available water-holding capacity is moderate, surface runoff is moderate, and erosion hazard is slight to moderate. These soils have slopes of 15 to 50%. Mean annual precipitation is about 46 cm (18 in), and mean annual air temperature is about 5 to 6 C (42 F). Lithic Haploboroll soil generally supports vegetation which is used for summer livestock grazing and

mule deer winter habitat. This soil has a severe limitation for sanitary facility uses due mainly to the shallow depth to bedrock (this includes sewage lagoons, septic tank absorption fields, and landfills). Use for local roads and streets is severely limited also. The soil is a poor source of material for roadfill or topsoil because of its thin layer, small stones, and problems or area reclamation.

Piceance series consist of moderately deep, well-drained soils that formed in residuum from sandstone and were modified with aeolian material. Effective rooting depth is 50 to 100 cm (20 to 40 in.). Organic matter content in the surface is medium. Infiltration is moderately rapid. Available water-holding capacity is moderate, surface runoff is slow to medium, and erosion hazard slight to moderate. Piceance soils are on upland slopes and ridges and have slopes of 5 to 15%. Mean annual precipitation is about 35 to 46 cm (14 to 18 in.), and mean annual air temperature is about 6 C (43 F). The vegetation grown on this soil supports livestock grazing and wildlife. Piceance soils have moderate to severe limitations for community development and sanitary facilities due to depth to bedrock. Recreational areas are moderately limited due to dustiness and depth to bedrock. The soil is a poor to fair source for topsoil and roadfill material due to depth to bedrock and borrow area reclamation.

Redcreek series consist of shallow, well-drained soils that formed in sandy material weathered from underlying calcareous sandstone. The effective rooting depth is 25 to 50 cm (10 to 20 in.). Infiltration is moderately rapid. The water-holding capacity is low, surface runoff is slow, and the erosion hazard is slight. Redcreek soils are on mountain sideslopes and ridges and have slopes of 5 to 30%. Mean annual precipitation is about 40 cm (16 in.), and mean annual air temperature is about 6 to 7 C (44 F). Vegetation on Redcreek soils are used for limited livestock grazing and wildlife habitat. These soils have a limited use for community development, sanitary facilities, and recreational areas due to steep slopes and depth to bedrock. The thin layer makes this soil unsuited for use as topsoil and source material for roadfill.

Rentsac series consist of shallow, well-drained soils formed in residuum from sandstone. Effective rooting depth is less than 50 cm (20 in.). Organic matter content in the surface layer is medium. Infiltration is rapid. Water-holding capacity is low, surface runoff is medium, and erosion hazard is slight to moderate. Rentsac soils are on foothills (upland entranched terraces) and have slopes which are 5 to 50%. Mean annual precipitation is 40 cm (16 in.), and mean annual air temperature is about 6 to 7 C (44 F). Rentsac soils are used for recreation and support vegetation that is used for livestock grazing. This soil has a severe limitation on sanitary facility uses due mainly to the depth to bedrock and slope (this includes sewage lagoons, septic tank absorption fields, and landfills). Local roads and streets are severely limited for the same reasons. As source material for roadfill and topsoil, Rentsac is poor due to its thin layer, small stones, and problems of area reclamation.

Yamac series consist of deep, well-drained soils that formed in alluvium and aeolian materials. Effective rooting depth is 150 cm (60 in.) or more. Organic matter content in the surface layer is medium. Infiltration is moderate. Available water-holding capacity is high, surface runoff is slow, and erosion hazard is slight. Yamac soils are on rolling uplands and ridges and have slopes of 2 to 15%. Mean annual precipitation is about 36 cm (14 in.), and mean annual air temperature is about 6 to 7 C (44 F). Yamac soils generally support vegetation used for livestock grazing and wildlife habitat. This soil is well suited for community development, sanitary facilities, and recreational areas. This soil is also a good source for topsoil and is fair for roadfill material.

Rock Outcrop-Torriorthents with 15 to 90% slopes occur mainly on southerly aspects in the Piceance Basin on strongly sloping to extremely steep terrace breaks of the many drainageways of this area. Rock Outcrop occurs as horizontal sandstone cliffs or dike-like outcrops and as platy siltstone outcrops in 50 to 65% of the mapping unit. The remainder of the mapping unit is comprised of Torriorthents, most of which are very shallow and shallow and a small percentage which are moderately deep and deep in the colluvial

and alluvial material. The vegetation of the Rock Outcrop-Torriorthents association is characteristically very sparse - few scattered pinyons, junipers, and shrubs. These soils have a severe limitation for sanitary facilities and local roads due to shallowness of the soil. These soils are a poor source of material for roadfill and topsoil because of their thin layer, small stones, and problems of area reclamation.

The Redcreek-Rentsac complex is moderately sloping to steep soils formed in residuum on foothill slopes and ridges at elevations of 1,800 to 2,300 m (~6,000 to 7,600 ft). Average annual precipitation is about 40 cm (16 in), and mean annual air temperature is about 7 C (44 F). The Redcreek soil makes up about 60% of the complex and the Rentsac soil makes up about 30%. Redcreek soil is similar to the Rentsac soil but is non-skeletal. About 10% of the complex is Rock Outcrop, Piceance fine, sandy loam, and Yamac loam.

The Rentsac-Piceance complex is gently sloping to moderately steep soils on sloping uplands, low mountain slopes and ridges at elevations of 1,900 to 2,200 m (~6,200 to 7,200 ft). Average annual precipitation is about 40 cm (16 in) and mean annual air temperature is about 6 C (43 F). The Rentsac soil makes up about 50% of the complex, and Piceance soil about 40%. About 10% ofthe complex is Redcreek sandy loam, Yamac loam, and Forelle loam soils.

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CHAPTER 13

TRACE METALS

SECTION 3

BASELINE CONDITIONS

TRACE METALS

The natural occurrence of trace metals in the biosphere has been documented. These trace metals are often by-products of industrial processes and enter the ecosystem through the air, soil, or water. Many of these trace elements are required in low concentrations by plants and animals, but in high concentrations can produce acute and chronic toxicity. Not only do individual metals produce potentially harmful effects, but metals may act together (synergistically) to produce an effect far greater than the sum of the individual metals. Conversely, the presence of one metal can reduce the toxicity of the other. Despite recent research in this area, most questions are unanswered, as evidenced by the paucity of available literature on trace metal cycling in the semi-arid west. Furthermore, the literature on trace metal cycling in an ecosystem is usually sparse or antiquated. The exceptions are some of the heavy metals, (mercury, cadmium, and lead) pesticides, and herbicides. When these interactions are viewed from a holistic approach, the picture is clouded and, at best, complex.

A number of factors influence the toxicity potential of any given metal in a dynamic system. They include:

1) soil texture,
2) Soil moisture availability,
3) the nature of the metal (free of bound),
4) evapotranspiration rates,
5) the species of plant or animal,
6) seasonal fluctuations,
7) the presence or absence of other constituents (organic and/or inorganic), and
8) organism age or stage of life cycle.

These factors may act independently or in combination in determing the cycling of trace metals in an ecosystem.

The goals of this program are to identify presence and concentration of trace metals in the soil. This information, in conjunction with soil data (e.g., texture, soil moisture release curves) and available literature, will determine if plants (terrestrial and/or aquatic) should be sampled for trace metals. If it is necessary to sample certain species of plants, then, following data analysis and interpretation, another judgement will be made as to whether or not sampling of first order herbivores (e.g., deer, long-tailed voles, etc.) should be conducted. Based on the results of the tests, this process could continue up to the highest order, the carnivore.

13.1 OBJECTIVES

The primary objectives of the trace metal program are to document presence or absence of toxic trace metals in the soil and, if present, determine their concentration, thereby identifying existing baseline conditions. Subsequent studies may be required in the plant and animal component of the ecosystem.

13.2 METHODOLOGY

The parameters which will be measured in analyzing soil samples are identified in Section 3-12.2. All analytical procedures can also be found in Section 3-12.2.

13.3 LITERATURE REVIEW

It seems appropriate to present the biological effects of some trace metals which are applicable to the environs of Tract C-a as identified from previous work and a detailed literature review. This summary information should provide some insight into trace metal effects and movement in terrestrial and aquatic ecosystems.

Since molybdenum, zinc, fluoride, and selenium have been reported in abnormal concentrations associated with oil shale development, they will be discussed in general terms as described in the literature. These four chemical constituents can impact both terrestrial and aquatic ecosystems if present in

sufficient amounts. Until their exact background concentrations are known, it will be difficult to determine their effects on the environs associated with Tract C-a (McKee and Wolf 1963).

A. Molybdenum - According to McKee and Wolf (1963), molybdenum in very low concentrations is essential to facilitate healthy growth of a number of plants and in certain microbiological systems where it acts as an enzymatic catalyst for nitrate reduction. Many legumes cannot complete their life cycle if the soil is molybdenum deficient, since nitrate-producing mechanisms require this element in trace amounts (Browning 1961).

At higher concentrations, molybdenum has been shown to be injurious to certain plants. Although the following plants are not associated with Tract C-a, they are presented below to depict injurious effects of varying concentrations of molybdenum.

Plant	Effect	Concentration in mg/liters of Molybdenum	Reference
Flax	Abnormal growth	0.5-100	Millikan 1949
Clover, Lettuce	Toxic effect	5.0	Joham 1953
Soybean	Toxic effect	10-20	Warington 1950
Cotton	Slight effect	25-35	Joham 1953
Oats	Slight effect	50	Hunter, Vergano 1953
Oats	Chlorosis	100	Hunter, Vergano 1955
Oats	Stunted growth	200	Hunter, Vergano 1953

Molybdenum is also known to act antagonistically when associated with other elements. Low concentrations of molybdenum reduced the toxic effects of manganese, cobalt, and nickel in flax, and nitrate injury to tomatoes (Millikan 1949).

Animals also require trace amounts of molybdenum for proper metabolic functioning and, as with plants, high concentrations tend to be toxic. Browning (1961) indicated the LD_{50} (the dose at which 50% of test animals

die during a set period of time) for rats was 125 mg/kg for molybdenum trioxide, 101 mg/kg for calcium molybdate, and 333 mg/kg for ammonium molybdate. When the toxic compounds containing molybdenum were compared, the following results were noted. When 500 mg of molybdenite (MoS_2) was injested daily, there was no reportable toxic effect; but, animals receiving the same dosage of molybdenum trioxide, calcium molydate, or ammonium molybdate showed anorexia, listlessness, and loss of weight. Molybdenum increased the mortality rate of rats fed a ration containing 11 mg/l of selenium in their drinking water (Moxan and Rhian 1943). Chicks fed a diet containing 300 mg/l (dry basis) of molybdenum experienced reduced growth rates during a 4-week period and then resumed near normal growth. Chicks administered 600 mg/l experienced suppressed growth through 8 weeks (Arthur, et al. 1958). Copper, however, appeared to antagonistically reduce the toxicity of molybdenum.

The principal impact of molybdenum to herbivores results from its rapid incorporation by plants into their foliage in similar soil types. Water-soluble molybdenum compounds in herbage caused severe cases of scour in cattle. Pastures where cattle had severe scour (caused by molybdenum) contained 20 to 100 mg/l of molybdenum, while pastures where cattle were not subject to scour contained less than 5 mg/l (Russell 1944).

Tarzwell and Henderson (1956) determined in an exploratory test using molybdic anhydride that the 96-hour TL_m (concentration which kills 50% of test animals in 96 hours) for fathead minnows was 70 mg/l in soft water (pH = 7.4, total alkalinity = 18, hardness = 20) and 730 mg/l in hard water (pH = 8.2, total alkalinity = 360, hardness = 400). Molybdenum appears to be essential for the growth of the green algae *Scenedesmus* sp., with the threshold concentration for deleterious effect being 54 mg/l (Arnon and Wessel 1953). Both the gram-positive bacteria *Escherichia coli* and the aquatic crustracean *Daphnia* sp. tolerated concentrations of 1000 mg/l without perceptible injury (Bringmann and Kuhn 1959).

B. Zinc - The precise biological effect of zinc will vary with compounds and physical and chemical conditions in the environs. Zinc salts such as

zinc chloride and zinc sulfate are highly soluble in water. On the other hand, zinc compounds such as zinc carbonate and zinc oxide are highly insoluble and would readily precipitate and be removed from natural waters.

Zinc is prevalent in many species of plants in amounts varying from 1 to 10 mg/kg (Browning 1961). Zinc in higher concentrations, however, can have a deleterious effect upon plants. Tomlinson (1956) indicated that the germination of cress and mustard seeds in an aqueous solution was retarded by the addition of 54 to 436 mg/l to the growth medium.

Zinc toxicity in animals, as in plants, will be determined by a number of factors such as size, age, and species of animal. Anderson, et al. (1934) found that rats showed no harmful effects when fed 50 mg/l of zinc in their water. In pigs (Anon 1950), 390 mg/l of zinc fed over 3 months produced no ill effect; however, when 1000 mg/l of zinc was fed as lactate, it caused lameness and malnutrition. In the domestic cat, there was no reportable injury when fed 5 mg/l of zinc as malate per day for 10 days (Moxan and Rhian 1943). When water-soluble zinc was injested by laying hens at a concentration of 10,000 mg/l, egg production dropped and water consumption decreased (Sturkie 1956).

The aquatic counterparts to the terrestrial animals are likewise affected by zinc. It is towards fish and aquatic organisms that zinc exhibits its greatest toxicity. Jones (1938) reported that the lethal limit of zinc in mature fish varies with the amount of calcium in the water. Apparently zinc can form insoluble compounds with the mucous on gill covers (Southgate 1955), damages gill epithelium (Lloyd 1960), or possibly acts as an internal poison (Kruse 1958).

Synergistically, copper seems to increase the toxicity of zinc in natural waters. Doudoroff and Katz (1953), Doudoroff (1952, 1957), and Tarzwell (1956) observed that test fish in soft water could tolerate a concentration of 8 mg/l of zinc for 8 hours. However, when 0.025 mg/l copper was combined with 1 mg/l of zinc in solution, all fish died within 8 hours (Doudoroff 1957). In addition to the zinc-copper interaction, Doudoroff (1952, 1956) reported

that zinc increased the toxic properties of cyanide by allowing dissociation of this zinc-cyanide complex in very dilute solutions.

C. Fluorides - A third potentially toxic chemical is the general class of substances called fluorides. These substances have been reported in existing hydrologic studies and could exert a potential impact during mine development.

Fluorides, because of their origin in certain types of rock and tendency to precipitate out in the presence of oxygen, are seldom found in natural waters, but can occur in high concentrations in ground water.

It has been reported that fluoride in natural waters or in polluted streams have little effect on plants (Russell 1944, MacIntire, et al. 1951, Smith, et al. 1945). In animals, low concentrations help retard tooth decay, but higher concentrations cause mottling of the teeth. In lactating cows, injestion of low concentrations of fluoride had no influence of fluorides in the milk. When 500 mg/l was injested, it increased fluorides in the milk by only 0.5 mg/l (Smith, et al. 1945); however, chronic fluoride poisoning of livestock has been observed where water contained 10 to 15 mg/l fluoride (Servisis, unpublished data).

In fish, fluoride ions appear to have direct toxic effects as indicated in Table 13.3-1.

D. Selenium - Although selenium in trace amounts appears to be essential for the nutrition of animals, very little is known about the mechanism of its action.

13.4 DATA SUMMARY

Soil samples have been collected on and adjacent to Tract C-a and are presently being analyzed at the Colorado School of Mines, and reports on the soil trace metals will be submitted to the AOSO upon completion of the soil segment of the program.

13.5 DISCUSSION

Discussion will be provided following data analysis and interpretation of the soil study. It will include potential for cycling of certain trace metals through the physical and biological components of Tract C-a if certain metals are found in high background concentrations. In addition any further sampling of the plant and animal component will be discussed with relevant methodologies included.

CHAPTER 14

ECOLOGICAL INTERACTIONS

14.1 INTRODUCTION

The data presented and the baseline conditions discussed in the previous 13 chapters of this section represent results collected after the first year of a two-year data gathering program. The study area was confined to Tract C-a, a 5-mile perimeter of the tract, the area designated for spent shale disposal, and for the aquatic studies, portions of Yellow Creek and the White River. The studies were designed to produce the type of data most effectively applied toward generating a description of baseline conditions.

The objectives of the baseline data gathering program as specified in the lease are to: compile data to determine existing conditions prior to development in the areas of air quality; meteorological conditions; surface and subsurface water quality and quantity; distribution, density, and condition of flora; identification, distribution, and abundance of fauna; description and distribution of soils; and ecological interrelationships.

In addition to meeting lease stipulations, there are several, more basic and important reasons for discussing ecological interactions for the study area. Analysis of these ecosystems from a holistic viewpoint provides a platform for integration of information collected during several different study programs into a succinct synthesis and description of baseline conditions. Additionally, the endeavor to characterize ecological interactions which specifically affect the ecology of the study area forces us to define and describe major components of the ecosystem which are currently affecting these systems. Once these factors have been described, this information can be used to select those parameters for future monitoring which are most likely to accurately reflect the effects of development. Components to be monitored can be selected on the basis of their role in the mainstream of ecosystem functioning, for their effect on other important components,

and for their sensitivity to environmental perturbation. It is important to understand that the interrelationships described herein are qualitative assessments, although the majority are based on quantitative data.

Ecological interactions encompass all the interactions between living organisms and their environment. Since the environment includes all physical, chemical, and biological factors to which an organism is subjected, the range of interactions, even within a small system, can be widespread and complex, and in some cases, extremely subtle. The lack of adequate technology, in combination with the complexity of the problem, make it impossible to discuss all the interactions which effect a given ecosystem.

The definition of an ecosystem can vary in respect to the magnitude, duration and production of the entity being described. The entire globe can be considered an ecosystem as can an island, a forest, a pasture, a decaying tree stump, or even a temporary pool.

The first step in the study of an ecosystem is to define its boundaries. This is preferably accomplished by delineating an area that is large enough to contain a complete complement of ecosystem components, and by placing its boundaries where inputs and outputs can be observed. In the case of Tract C-a, the boundaries of the study area were arbitrarily established to coincide with the boundaries of the leased land and adjacent areas previously mentioned. These boundaries encompass seven distinct vegetation communities and four types of aquatic habitat.

Once the boundaries of the ecosystem(s) to be studied have been established, the second step is to identify the significant components within that ecosystem. The components discussed herein represent a major portion of the standing crop and/or occupy a vital position in the nutrient pathway. The breakdown of components is limited to a level which can reasonably be discussed in view of the available data.

The four major groups of components common to all ecosystems are:

- abiotic components

- producers
- consumers
- decomposers

A. Terrestrial Abiotic Components - Several abiotic components of the terrestrial ecosystem (Table 3-14-1) have been selected because of their importance to ecosystems in general and to Tract C-a in particular. Specifically, carbon dioxide, water, and oxygen are discussed because of their importance in respiratory and photosynthetic (energy flow) pathways.

Table 3-14-1

ABIOTIC COMPONENTS WHICH AFFECT THE TRACT C-a
TERRESTRIAL AND AQUATIC ECOSYSTEMS

Terrestrial Components		Aquatic Components
Carbon dioxide	Insolation	Groundwater chemistry
Water	Precipitation	Surface water chemistry
Oxygen	Wind	Sediment chemistry
Soil texture	Evaporation	Substrate
Soil moisture	Elevation	Water temperature
Soil chemistry	Topography	Water volume
Slope aspect		

Soils vitally influence plant diversity and distribution, nutrient cycling, and moisture retention. Soil texture affects plant rooting depth, moisture availability, drainage capability, and erodability. Soil moisture affects production of vegetation biomass, influences plant species composition and plant distribution. Soil chemistry is determined by the parent material and changes as concentrations of nutrients, salts, allelopathic plant toxicants, and other chemical substances vary. These factors in turn affect plant distribution, species composition, growth rate, and rate of decomposition.

Slope aspect describes the orientation (direction) of the slope face with respect to the sun. Slope aspect is especially important in semi-arid

regions in the northern hemisphere because south-facing slopes are always exposed to the sum. This causes accelerated evaporation rates and generally provides a more harsh environment than do north-facing slopes. Factors related to slope aspect include depth of topsoil, vegetative cover, insolation, and rate of evaporation.

Insolation is important in generating local (drainage) winds and increasing both evaporation rate and air temperature. Intensity of insolation varies with cloud cover, geography, and air quality. Vegetation cover, soil litter, slope aspect, and soil color affect reflection or absorption of solar energy.

Precipitation affects the amount of soil moisture available to plants and thereby influences their abundance, distribution, and species diversity. It also affects rate of erosion and weathering of exposed surfaces and helps shape local terrain. Ramifications of these effects depend upon the rate and nature (state) of the precipitation, frequency of occurrence, association with wind, local topography, and long-term regional climate.

Strength, direction, and frequency of winds act on the ecosystem by affecting rate of erosion, evaporation rate, and physical form of plants. The nature of local winds is influenced by topography, geography, dense plant cover (e.g., pinyon-juniper, Douglas-fir), and insolation.

Evaporation rate affects availability of surface water to animals and microclimate (humidity) and influences desiccation of living tissue. Evaporation rate varies with insolation, air temperature, wind speed, slope aspect, vegetation cover, relative humidity, soil color, and texture.

B. <u>Aquatic Abiotic Components</u> - Six separate abiotic components of the aquatic ecosystem are discussed (Table 3-14-1). Among them, groundwater chemistry must be considered because of its important contribution to the quantity (and quality) of surface water supplies (e.g., springs and seeps). Groundwater chemistry is largely determined by the presence or absence of soluble salts in subsurface geologic formations.

Surface water chemistry (and quantity) affects success of living organisms in the aquatic environment by influencing nutrient availability, dissolved oxygen, pH, and alkalinity. Chemistry of surface water resources in the study area varies with rate of dilution, quality of surface and subsurface runoff, and chemical characteristics of stream bed.

Chemical characteristics of sediment affect the nature of bottom fauna and contribute to the chemistry of the surface water. These chemical constituents are largely derived from surface runoff and precipitated salts.

The nature of the substrate affects rate of flow, dissolved oxygen, and diversity and abundance of the bottom flora and fauna. Substrate type is primarily determined by local geology and stream velocity.

Water temperature is an important constituent of aquatic interactions because of the role it plays in metabolic activity of aquatic organisms, concentrations of dissolved salts and gases, and evaporation rate. Temperature of the waters in the study area is largely determined by turbidity, velocity of flow, depth, air temperature, wind, and input from surface and groundwater supplies.

Water volume is important because it influences velocity, turbidity, chemical concentrations, and constituency of substrates. Water volume is affected by severity of local thunderstorms, snowmelt, groundwater contribution, and rate of surface runoff.

C. Terrestrial Producers - The producer components (Table 3-14-2) of the terrestrial ecosystem are defined in terms of seven major vegetation communities found in the area. The basic function of producer components in the energy-flow, nutrient cycle of ecosystems is briefly reviewed in part 14.2 of this chapter. In addition, each of the seven major vegetation communities will be briefly described. Basic reasons for distinguishing these particular components are that each occupies a major portion of the standing crop biomass, they are highly diverse and provide food for a wide variety of consumers,

Table 3-14-2

BIOTIC COMPONENTS WHICH AFFECT THE TRACT C-a

TERRESTRIAL AND AQUATIC ECOSYSTEMS

Terrestrial Producer Communities	Aquatic Producer Communities
Pinyon-juniper	Periphyton
Sagebrush	Phytoplankton
Mixed brush	Macrophytes
Aspen-Douglas-fir	
Upland meadow	
Riparian	
Greasewood	
Terrestrial Consumer Groups	**Aquatic Consumer Groups**
1st order	1st order
Large mammals	Benthos
Small mammals	Zooplankton
Birds	Fish
Invertebrates	
2nd and 3rd order	2nd order
Mammalian predators	Benthos
Avian predators	Zooplankton
Invertebrate predators	Fish
Decomposer Groups	
Microfauna	
Bacteria	
Fungi	

or because a large portion of the vegetation biomass within the cummunity is utilized by consumers (i.e., palatability is high).

D. Terrestrial Consumers - Three levels of terrestrial consumer groups (Table 3-14-2) occur in the study area. First order consumers feed on plant material and include large mammals (cattle, elk, mule deer), small mammals (mice, squirrels), birds, and invertebrates. The impact of these consumers can drastically affect vegetative growth of producers and populations of other consumers in competition for the same food source. Second order consumers found in the study area include coyotes, bobcats, weasels, badgers, shrews, red-tailed hawks, and others. These consumers affect the population dynamics of first order consumers which serve as their prey species (rabbits, rodents, birds, invertebrates, and so forth). Third order consumers which occur in the area include the same groups as the second level consumers since their roles change in different food webs.

E. Aquatic Producers - Table 3-14-2 lists aquatic producer communities to be discussed in this paper. Of these, only one, periphyton (attached algae), contributes significantly to primary production in the intermittent streams on Tract C-a. Phytoplankton (floating algae) and macrophytes (rooted aquatic plants) are of secondary importance since their abundance within the study area is so limited that these producers contribute very little biomass to the aquatic ecosystem.

F. Aquatic Consumers - Two levels of aquatic consumers are discussed, first and second order consumers (see Table 3-14-2). The demarcation between aquatic consumer groups is not distinguished as easily as it is for terrestrial ecosystems because of seasonal variation in diet. First and second order consumers include benthic organisms, zooplankton, and fish.

G. Decomposers - The decomposer group consisting of bacteria, fungi, and microfauna is extremely important in the cycling of nutrients within all ecosystems. The biomass produced at all trophic levels is eventually recycled by the action of decomposer organisms.

14.2 SYSTEM INTERRELATIONSHIPS

Ecosystems reflect the dynamics of complex nutrient cycling and energy flow pathways. The aquatic and terrestrial ecosystems of Tract C-a share the basic principles involved in these pathways; therefore, a review of these principles is presented and related to the systems interactions on Tract C-a.

A. Energy Flow - The ultimate source of earth's energy is the sun. Light energy enters the earth's atmosphere in the form of visible light (wave length of 400 to 760 mμ), ultraviolet light (<400 mμ), or infrared light (>760 mμ). Most ultraviolet light and some visible and infrared light is absorbed by the ozone layer in the upper atmosphere. Additional light energy is absorbed by lower layers of the atmosphere so that the total light energy which finally strikes the earth's surface is only about 43% of the amount radiated to the earth from the sun. Sea level areas receive less solar energy than do mountainous regions because of the greater density and thickness of the atmosphere at sea level.

Once light energy strikes the surface of the earth, a great deal of it is absorbed by land and water and a small fraction (about 8%) strikes green plants. It is at this point that conversion of solar energy into potential (usable) energy begins. Usually less than 3% of the light which actually strikes a plant is used in photosynthesis. Light energy which is trapped by chloroplasts within the plant leaf drives the process known as photosynthesis in which carbon dioxide and water are combined to form simple sugar and oxygen. This triggers the process known as the carbon-hydrogen-oxygen cycle, better known as the carbon cycle. Key components of photosynthesis are indicated below:

$$\text{Water + Carbon Dioxide} \xrightarrow[\text{Chlorophyll}]{\text{Light Energy}} \text{Sugar + Oxygen + Water}$$

The sugar thus produced is utilized by the plant for its energy needs or is stored as sugar or some more complex form as plant biomass. The biomass

produced by primary producers during photosynthesis is the ultimate source of potential energy for all other forms of life. Energy rich carbon compounds are transferred through the ecosystem through the carbon cycle (Figure 3-14-1). During its flow through the ecosystem from plant to consumer to decomposer, energy is steadily lost to the system in the form of heat radiation, respiration and waste. This steady loss of energy in each succeeding trophic level causes a gross reduction in numbers of organisms that can be supported at each higher level. Estimates of ecological efficiencies are difficult to obtain, and a great deal of confusion exists over the real meaning of this concept (Smith, 1974). Since energy is not cycled, ecosystem endurance depends upon a continuous input of light energy. In addition to light energy, the critical components of photosynthesis are water, carbon dioxide, and chlorophyll.

B. Nutrient Cycling - With the exception of energy, which flows into the system on a continuous basis, the global ecosystem is basically closed. Nutrients and water levels do not, for all practical purposes, increase or decrease. Instead, they flow through ecosystems in never ending cycles. The nutrient cycles are repeated many times within regional and local ecosystems.

Two of the most critical nutrient cycling pathways in natural ecosystems are the carbon-hydrogen-oxygen cycle (already mentioned) and the nitrogen cycle. In the carbon cycle (Figure 3-14-1), biomass produced by plants is utilized by the plant itself, by consumers, or by decomposers. Animal (consumer) biomass is eventually recycled by decomposers also, but may appear as biomass in several intermediate consumers in the meantime. The cycling of carbon, hydrogen, and oxygen through the system is accompanied by energy losses through respiration, body heat, and metabolic activities and biomass and water loss through waste excretion and evapotranspiration. Nutrient replacement occurs by the addition of carbon compounds through weathering of carbonate minerals and combustion, and by the supply of oxygen from the air. Water losses are offset by precipitation, condensation, and groundwater infiltration.

The limitations imposed upon the process of photosynthesis, the carbon cycle and many other vital ecosystem functions by the availability of water, place

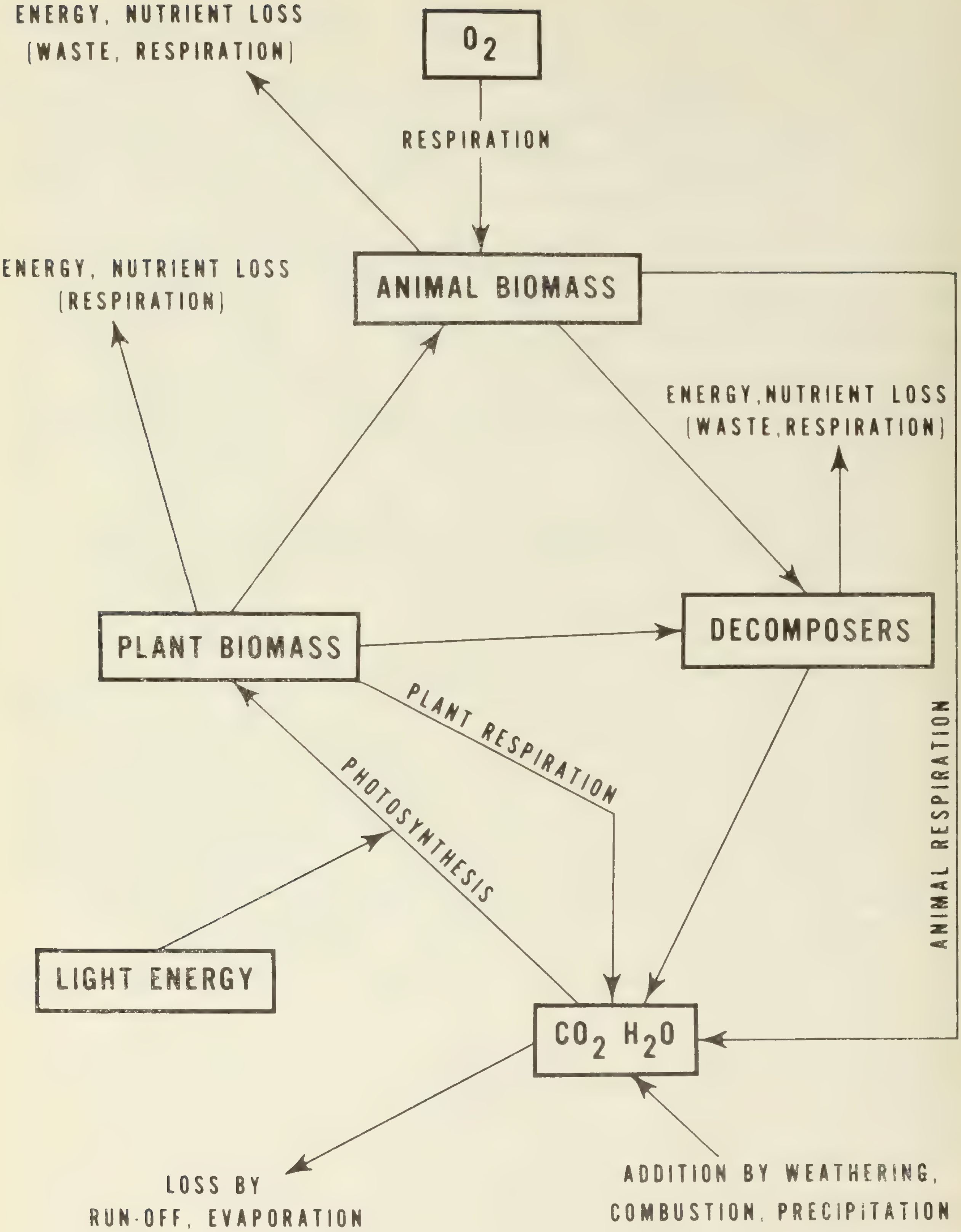

Figure 3-14-1

SIMPLIFIED REPRESENTATION OF THE CARBON-HYDROGEN-OXYGEN CYCLE

water first in importance to survival and continuation of living systems. The earth's supply of water is limited and not evenly distributed. The distribution and abundance of water is controlled by regional and local climatic conditions as well as subsurface geological characteristics. The water cycle is global and from a regional perspective, especially in semi-arid regions, cannot always be identified as cyclic. The water (hydrologic) cycle is illustrated in Figure 3-14-2. Water which falls to the earth as rain or snow enters streams or springs as surface or subsurface runoff where it eventually flows to oceans or lakes. This water re-enters the cycle by evaporation to the atmosphere from lakes, streams, oceans, or from plants and animals. The cycle is completed when clouds are formed and the water returns to the earth's surface as precipitation.

The role of nitrogen in ecosystem functioning is similarily important, but the mechanism of cycling is somewhat different. Nitrogen is an essential element in all proteins and nucleic acids. The production of simple sugars during photosynthesis and their subsequent conversion to more complex proteins and nucleic acids are dependent upon the availability of nitrogen.

Nitrogen occurs abundantly in the earth's atmosphere as gaseous N_2, but it cannot be utilized by plants or animals in its molecular form. The process of nitrogen conversion is shown in Figure 3-14-3. Conversion processes include the action of nitrogen fixation by bacteria and algae in soils and some legume roots, and nitrification by soil bacteria.

Plant or animal tissue and waste products are converted to gaseous ammonia by decomposer organisms. The ammonia then reacts with water to form ammonia salts. These salts ionize to ammonium (NH_4+). Some ammonium ions are taken up directly through plant roots. Others are oxidized by nitrifying bacteria into water and nitrites (NO_2^- salts). Some of these nitrites are oxidized by other bacteria into nitrates (NO_3^- salts). These nitrates are taken up through the roots and utilized by green plants. Conversion of atmospheric nitrogen into ammonia and finally nitrites and nitrates by nitrogen-fixing bacteria or algae occurs in the soil or in the roots of legumes. The nitrogen cycle has several leaks (Figure 3-14-3), including loss by erosion and leaching,

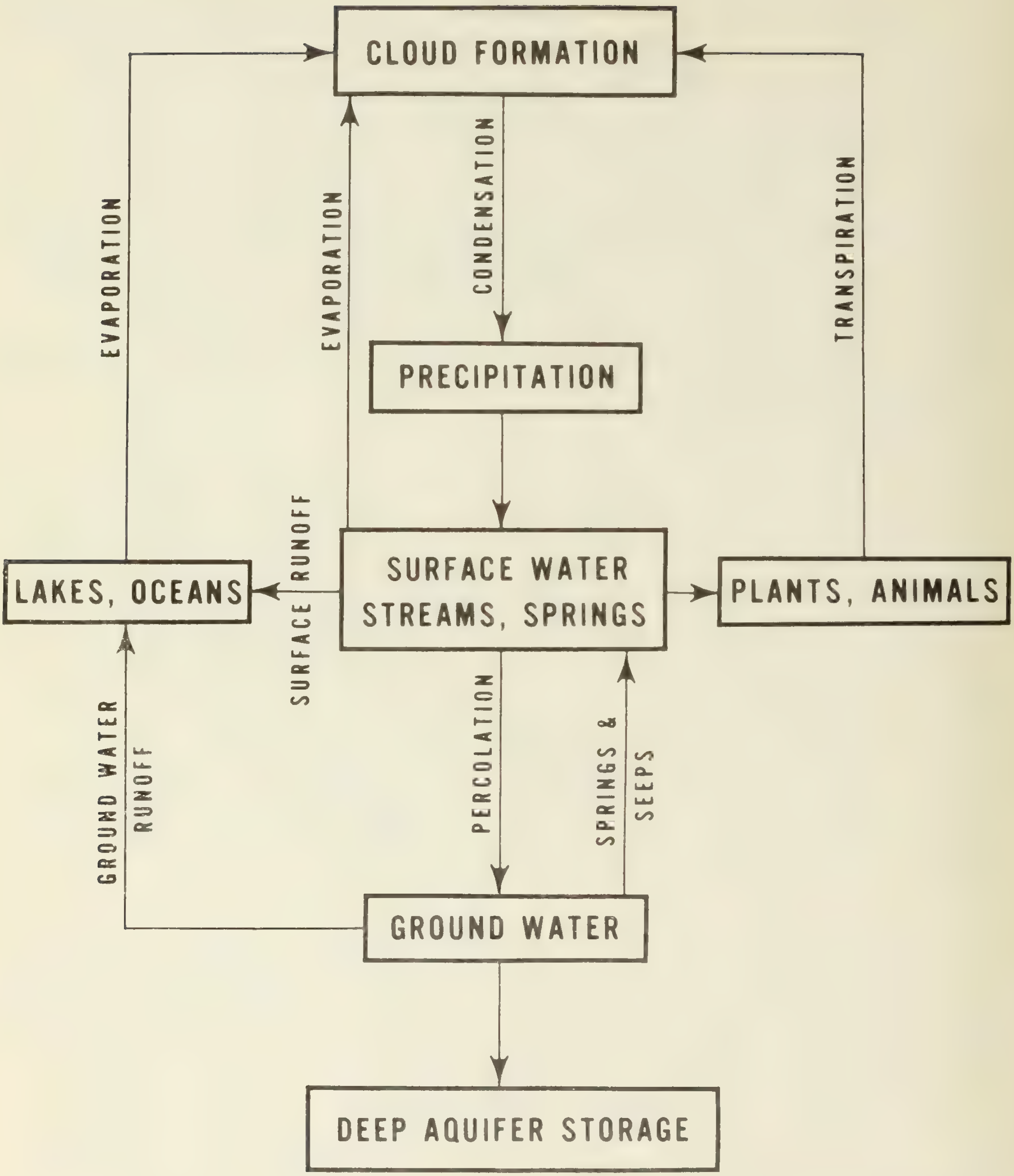

Figure 3-14-2

HYDROLOGIC CYCLE

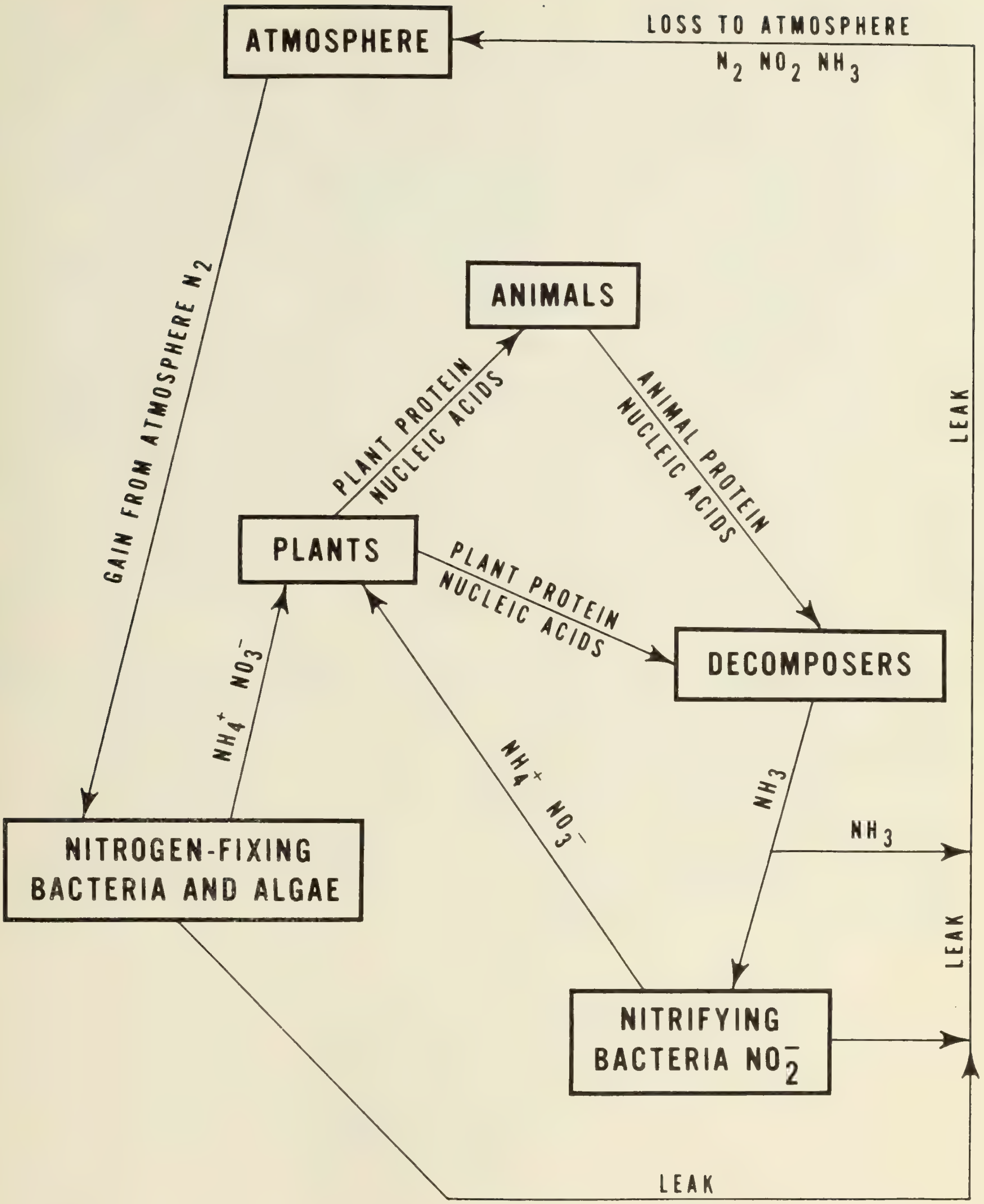

Figure 3-14-3
SIMPLIFIED REPRESENTATION OF THE NITROGEN CYCLE

and loss of gaseous ammonia to the atmosphere.

Only two nutrient cycles, carbon-hydrogen-oxygen and nitrogen, are discussed here. These nutrients fall under the classification of "macronutrients". Certain "Macronutrients" also affect the functioning of ecosystems. Macronutrients are normally required in relatively large quantities to sustain life, while micronutrients are required in smaller quantities but are essential in the operation of living systems. Other macronutrients include: potassium, calcium, magnesium, sulfur, and phosphorous. Micronutrients required for primary production include: iron, manganese, copper, zinc, boron, sodium, molybdenum, chlorine, vanadium, and cobalt. Some nutrient cycles are more or less "closed"; that is, the material is returned to the environment as fast as it is removed and there is little or no change in the distribution of the element in the ecosystem. Other cycles are less perfect in that some portion of the supply may get "lost" or become inaccessible for long periods of time (e.g., the phosphorous cycle). All, however, exhibit definite biogeochemical cycling tendencies.

The nutrient and energy flow pathways just discussed form the framework of ecological interactions within ecosystems. Figure 3-14-4 diagrammatically represents the relationships of these pathways as they occur in the study area. The diagram is, of course, a gross simplification. Identification of all environmental stimuli which affect an ecosystem is not easily nor realistically documented. However, generalizations can be made which help clarify the dynamics of ecosystems.

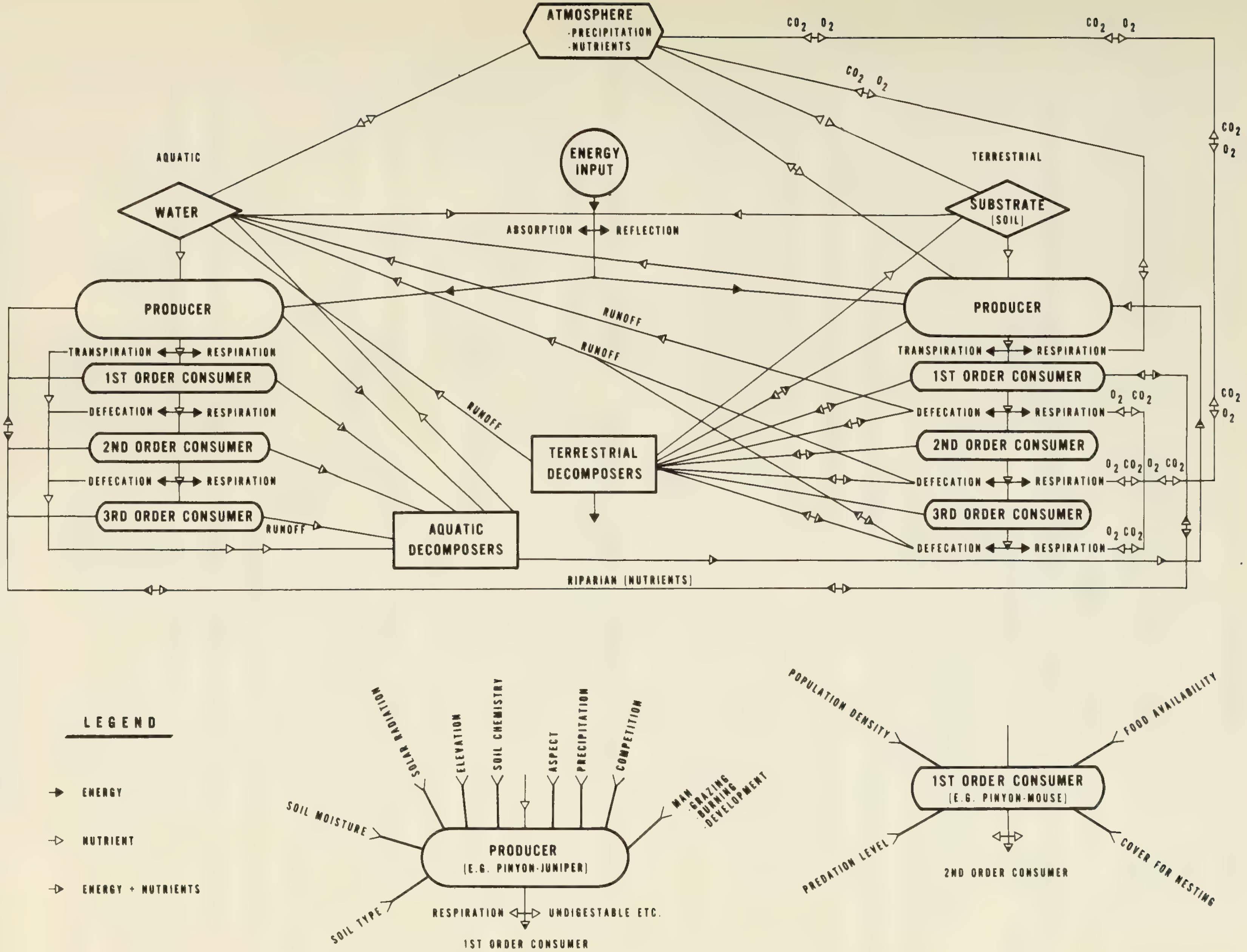

Figure 3-14-4
ECOLOGICAL INTERACTIONS ON TRACT C-a

14.3 ECOSYSTEMS INTERACTIONS

This section addresses some interactions which are known to occur in the study area. Specific quantitative data are largely omitted for ease of reading. These data, however, appear within earlier chapters of this section as a part of the baseline description. The reader who is interested in site-specific data should refer to these chapters.

A. Terrestrial Interactions - Seven major vegetation communities occur in the study area. Three of these communities, pinyon-juniper, sagebrush, and mixed brush, characterize 90% of the total study area; however, aspen-Douglas-fir, upland meadow, riparian, and greasewood communities also occur to a lesser extent. Pinyon-juniper, sagebrush, and mixed brush communities are discussed in greater detail in this paper because of the area they occupy and because of their importance to wildlife. Other community types are covered in a cursory manner.

1. Pinyon-Juniper Community Interactions - The pinyon-juniper community is dominated by pinyon pine (*Pinus edulis*) and/or Utah juniper (*Juniperus osteosperma*). This community type encompasses 70% of the study area and is located primarily on ridge tops, spilling over and down ridges on both north-east- and southwest-facing slopes. In some areas canopy is tight, allowing little light penetration and understory is sparse. Understory is more prevalent in areas of less dense canopy cover but is seldom dense (8-11% average cover). The elevational distribution of this community ranges from 1,520 m on the east side of the tract to 2,280 m west of the tract and may, at times, include lower elevations (e.g., zone inversion in canyons). Sagebrush is the most common shrub in the shrub stratum of this community, followed by Utah serviceberry. Three grasses which commonly occur in the herbaceous stratum are slender wheatgrass, sandberg bluegrass, and Indian ricegrass. There are basically two pinyon-juniper associations based on elevational distribution within the tract (lowland and upland) environs; however, higher order animal distribution and composition are similar in both types.

a. Abiotic-Biotic Interactions - In understanding the ecological

interactions of the pinyon-juniper community, awareness of the role the physical environment plays in distribution and abundance of this community is necessary. The primary factor influencing pinyon-juniper distribution is available soil moisture in the rooting zone.

The soils common to pinyon-juniper woodlands in the area are in the Rentsac series -- shallow, well-drained soils with effective rooting depths of less than 50 cm. Upland pinyon-juniper communities are commonly dominated by pinyon pine where the soils are well-developed mollisols. Lowland communities are dominated by juniper in areas where the substrate is composed of dry, poorly-developed aridisols. Where the two types of soils meet, the dominance by pinyon or juniper is not well-defined.

Physical-chemical nature of the soil determines rate and depth of percolation of water and nutrients. The fine, sandy loam soils common to pinyon-juniper communities of the study area have a low water-holding capacity. Infiltration is rapid, with a moderate surface runoff. Low availability of soil moisture to plants greatly limits formation of a diverse vegetation cover with soil-producing and soil-retaining properties. Lack of adequate soil buildup further prevents invasion by plants and limits community diversity. Therefore, shallow, low organic content, dry soils characteristic of pinyon-juniper communities tend to be perpetuated.

Lack of available soil moisture in pinyon-juniper communities is even more pronounced in those that occur on south-facing slopes. These slopes typically receive more insolation than north-facing slopes because of the position of the sun in northern latitudes. Prevailing winds of the area are also southwesterly. These two factors combine to reduce soil moisture by increasing evaporation rate. While pinyon pine and juniper are both suitably adapted to these especially harsh environmental conditions, few understory species are; therefore, pinyon-juniper communities on south-facing slopes are characterized by an even less dense and less diverse understory than communities on other slope aspects exhibit.

The character of pinyon-juniper communities can also be greatly modified by

fire. As pinyon-juniper communities mature, the litter becomes concentrated with allelopathic toxicants which inhibit germination and growth of new seedlings -- pinyon pine or juniper as well as other species. Thinning of the canopy cover by fire also increases availability of sunlight and directly influences availability of nutrients.

b. Producer-Producer Interactions - The producers within pinyon-juniper communities interact with each other in three important ways: by competition for soil moisture, competition for sunlight, and allelopathic inhibition.

Soil moisture is stored in various soil layers which are filled by seepage and emptied by evaporation at different rates. Each of these stores is utilized by plants with different time strategies, root systems, and other special mechanisms. The dominant plant type in an area is the one which can most effectively utilize the store of water available (i.e., pinyon-juniper). Specialized niches which allow utilization of water from other water stores result in the coexistence of the dominant plant type with other plant species (i.e., herbaceous understory).

Within the pinyon-juniper community, competition for soil moisture appears to be greatest in the herbaceous stratum, although dominance of pinyon pine over juniper at higher (wetter) elevations may reflect this sort of competition (Woodbury, 1947). Data indicate that competition for available soil moisture is more important than any other single factor in the distribution of understory species in pinyon-juniper communities (Johnson, 1962; Arnold, 1964). The herbaceous strata are affected by both the quantity and time of precipitation. Some resistent perennials are favored by drought conditions and, after several dry years, may assume dominance of the stratum. This drought resistence is made possible by reduced moisture requirements, shortened germination time, and favorable timing and intensity of flowering. Both species diversity and spatial distribution are influenced by this interaction.

Mature pinyon-juniper stands often have dense canopy covers which limit the amount of sunlight that can reach the understory stratum below. This

limitation can inhibit growth of species which require abundant sunlight, although some herbaceous species are known to do quite well in shaded areas. The dense canopy cover of some of these stands, however, probably contributes significantly to limited species diversity of the understory. The role of fire in relieving the limitation imposed by canopy cover has already been mentioned. The rapid takeover of burned-out pinyon-juniper communities by sagebrush and perennial grasses (Frischknecht, 1975) cannot be solely attributed to decreased canopy cover, however, because reduced competition for soil moisture and release from allelopathic inhibition also play vital roles.

Allelopathy is the direct or indirect harmful effect by one plant on another through the production of chemical compounds that escape into the environment (Rice, 1974). The ramifications of allelopathic processes within vegetation communities are not completely understood, but one important expression of allelopathy is "patterning". Patterning is the term used to describe the spatial arrangements of individual plants. Patterning is in part due to competition for water, sunlight, and nutrients, but some of the patterning within pinyon-juniper communities has been directly linked to allelopathy. The major sources of allelopathic toxicants in pinyon-juniper communities appears to be the litter (Jameson, 1966) and the roots (Jameson, 1970).

Rice (1974) identified 14 categories of allelopathic toxicants (inhibitors) and 10 mechanisms by which they operate. Plant litter in pinyon-juniper communities appears to prevent germination and growth of seedlings. Many of the pinyon-juniper communities in the study area are approaching maturity and exhibit characteristics attributed to these communities: sparse understory and low animal diversity. Other stands are less mature, with less canopy cover and slightly more understory cover and diversity, but understory is seldom dense. These characteristics are related to low available soil moisture, competition for light, and allelopathic inhibition.

c. Producer-Consumer Interactions - The producer-primary consumer interactions within pinyon-juniper stands are partially limited by senility and corresponding low plant species diversity of the community. Lack of dense understory in older pinyon-juniper communities has already been mentioned.

Limited plant diversity results in limited animal diversity because of deficiency of suitable, diverse habitats and lack of food and cover. Of the two co-dominant species, pinyon pine is more important in the food web than juniper. Pinyon pines grow rapidly and produce cones with large, readily available seeds which provide an important food source for rodents. Young pine shoots are eaten by rabbits, deer, elk, and rodents. Pinyon pine shoots, unlike junipers, do not become heavily laden with cellulose even during winter and therefore can be used as winter browse.

Pinyon-juniper stands provide protection from wind and also serve as loafing areas for large herbivores,and rodents use these stands for cover from predators. Both species of plants support heavy populations of leaf-eating insects, and grasshoppers feed on juniper berries. Additional utilization of the pinyon-juniper communities is largely dependent upon the species diversity and abundance of the understory. Cattle graze the area during warmer months and feed heavily on grasses and forbs associated with these communities. Feral horses, elk, and mule deer also utilize the associated vegetation to various degrees.

Moderate deer browsing within pinyon-juniper stands to the east of the tract has stimulated browse growth and enhanced the conditions of the range there. Deer crop back seedlings of both pinyon pine and juniper which results in the thinning of the forest and allows other, more palatable species to invade the community. As species diversity within these communities increases, animal populations increase and become more diverse, thus affecting consumer-consumer interactions within the community. Grazing by cattle and feral horses has the opposite effect. They tend to reduce the availability of herbaceous species and enhance invasion by the less palatable species, especially when grazing is heavy. Extremely heavy browse utilization can also be detrimental.

2. Sagebrush Community Interactions - Probably the most conspicuous association in the study area is the sagebrush community, its dominant species being big sagebrush (Artemesia tridentata). This community is common in all major drainages associated with the tract and it also occurs on the sides of ridges below pinyon-juniper and mixed brush communities. It ranges in

elevation over most of the study area. Two community types (upland and lowland) are found in the area. Sagebrush associated with upland sites is much smaller than lowland sagebrush. Upland sagebrush communities are usually associated with junegrass, wheatgrass, and needle-and-thread grass. Wheatgrass and Indian ricegrass are common understory species in lowland sagebrush areas. Understory is sparse where shrub cover is dense, but grasses are relatively abundant where the overstory is broken.

a. Abiotic Interactions - The soil type (parent material) and availability of moisture are major abiotic components influencing interactions in the sagebrush community. Lowland sagebrush is commonly found on deep alluvial soils of the Glendive series. Upland sagebrush most commonly occurs on mixtures of moderately deep aeolian and residual soils (Rentsac and Piceance series), moderately deep Yamac series soils, and shallow Rentsac series soils.

Bottomland sagebrush is restricted to lower reaches of drainage areas where more moisture is available. As the sagebrush community extends upward from the drainage basin, lowland sagebrush ecotypes are replaced by upland sagebrush type plants. Upland sagebrush is more widespread than lowland sagebrush and occurs wherever appropriate soil types are found. Upland sagebrush is found on level areas of 84 Mesa and slopes and ridges of the tract extending almost to the summit of Cathedral Bluffs. Cover increases with elevation in the upland sagebrush associations, but not so in lowland sagebrush associations. These cover differences probably reflect a more reliable moisture supply in bottomland sagebrush stands.

b. Producer-Producer Interactions - Major interactions at the producer level in sagebrush communities are in response to competition for available moisture in association with soil type. In the bottomland sagebrush association, soils are derived from alluvial deposits and are well drained with little or no salinity. They are usually dominated by big sagebrush, which reaches heights of 2 m and has a dense canopy. Rabbitbrush and shadscale are common shrub components, but greasewood will invade if salinity levels in the soil increase.

Upland sagebrush associations are the most mesic of the big sagebrush types. Here, big sagebrush attains heights of less than 1 m and is usually accompanied by Utah serviceberry and mountain snowberry shrubs. Competition for limited soil moisture is apparently responsible for the smaller size of plants on these upland areas.

The greatest plant species diversity found in these communities occurs in the transition zone between residual and alluvial soil types. This high diversity of producer components provides additional niches for consumers and increases producer-consumer interactions.

c. Producer-Consumer Interactions - The sagebrush community provides suitable habitat for a wide variety of animals, both resident and migratory. The sage grouse, Brewer's sparrow, and the sagebrush vole are commonly associated with this community. The sage grouse and Brewer's sparrow utilize it for courtship, nesting, and food. The sagebrush vole also uses this habitat for food and cover, but it prefers the transition zone between sagebrush and bottomland meadow communities.

Large ungulates (cattle, horses, and deer) frequently utilize the herbaceous strata for grazing, and both cattle and mule deer feed on sagebrush occasionally, especially when preferred foods are in short supply. However, organic oils and chemicals found in sagebrush can upset digestive processes if excessive amounts are consumed. Primary production of browse in sagebrush communities of the study area averages 209 kg/ha. This high level of browse production and the areal extent of these communities make them an important source of forage.

3. Mixed Brush Community Interactions - The third major community in the study area is mixed brush which occupies elevations of 2,160 to 2,615 m to the west of the tract where precipitation is relatively high. Species found in association within this community type include Utah serviceberry (*Amelanchier alnifolia*), antelope bitterbrush (*Purshia tridentata*), mountain snowberry (*Symphoricarpos oreophilus*), Gambel oak (*Quercus gambelli*), and mountain mahogany (*Cercocarpus montanus*). Although all of these species rarely

occupy the same community stand, dominance in an area by one or more of these species constitutes a mixed brush community. Mixed brush intergrades with aspen on the steeper slopes of the study area and with pinyon-juniper communities at the lower elevations. Two associations, Utah serviceberry-Gambel oak and Utah serviceberry-mountain snowberry association, comprise these mixed brush communities in the study area.

a. Abiotic-Biotic Interactions - Abiotic factors which influence distribution and diversity of mixed brush communities include elevation, soil moisture, soil type, slope aspect, and topography. Mixed brush communities in the study area are restricted to elevations above 2,160 m. They occur in protected topographic positions such as gullies and north- or east-facing slopes where there is abundant moisture. Species which comprise mixed brush communities have higher water requirements than either sagebrush or pinyon-juniper community species. In addition, Gambel oak requires more moisture than is required by the other mixed brush species. Chokecherry, snowberry, big sagebrush, and mountain mahogany may become local dominants or may share dominance along the moisture gradient (Ward et al., 1975).

Soil type also plays an important role in the development of this community. Mixed brush requires rather deep mollisols. Although mixed brush occurs on various types of terrain, the best developed communities occur on steep east-facing slopes.

The Utah serviceberry-Gambel oak association is characterized by a dense shrub layer and the presence of Gambel oak. Preliminary analysis of distribution data indicates that this association has a narrow elevational range and is primarily restricted to high, cool, (northeast-facing) steep slopes. Gambel oak dominates in areas where a good deal of moisture is available. Gambel oak cannot tolerate heavy grazing, strong winds, wide variations in temperature, or deep shade, although it has a wide range of tolerance to soil types.

The Utah serviceberry-mountain snowberry association is characterized by widely separated serviceberry plants interspersed with mountain snowberry. This association is found at lower elevations on drier, more gentle slopes

than the Utah serviceberry-Gambel oak association. Although the elevational ranges of these two associations overlap, they require different moisture conditions and topographic requirements.

b. Producer-Consumer Interactions - The mixed brush community produces more available browse than any other community in the study area, with an average production of 271 kg/ha of browse. This is 2.5 times greater than browse production of the pinyon-juniper community. In addition, species diversity of consumers is high, probably indicative of the vegetation diversity associated with this type.

There appear to be no consumer species unique to this community; however, many species utilize the community for feeding, cover, and nesting. This community appears to be a transitional zone for birds and large mammals. While several species of birds occur in the area, they rarely occupy the area for extended periods of time. It appears that deer utilize this community heavily for browse during migration. However, their wintering area is several kilometers east of the mixed brush communities. These areas are probably used as feeding areas by mule deer during mild winters. One of the mixed brush communities occurs within the home range for feral horses in the area and probably provides significant forage for these animals.

4. Interactions Within Other Community Types - The other four communities, their dominant plant species, and location are:

- Aspen-Douglas-fir - Aspen (*Populus tremuloides*) and Douglas-fir (*Pseudotsuga menziesii*) dominate these communities which are found above 2,584 m.
- Upland Meadow - These communities are dominated by grasses and/or herbaceous species. Dominance depends on aspect, slope, elevation, and grazing pressure.
- Greasewood - These communities, dominated by the species *Sarcobatus vermiculatus*, are frequently encountered in association with lowland sagebrush. Presence of greasewood in an area indicates a highly alkaline soil.

- Riparian - Willows (*Salix* sp.) and cattails (*Typha* sp.) dominate these communities which are found near springs or ponds.

a. Aspen-Douglas-fir Community Interactions - The aspen-Douglas-fir community types occur at higher elevations (above 2,690 m) west of the tract. Aspen and Douglas-fir mingle at these elevations with Douglas-fir more prominent on higher areas. The two species require larger amounts of moisture than do the other communities previously discussed. Aspen occurs on north- and east-facing slopes on deep, sandy loams with large accumulations of organic matter. Douglas-fir is restricted to summit areas of Cathedral Bluffs. Although aspen is often succeeded by Douglas-fir, this does not appear to be happening in the study area as the aspen communities appear to be self-sustaining.

Producer-producer interactions within the study area are unique within the aspen communities because of clonal (sharing a common root system) reproduction. The result is a well-spaced pattern of aspens. The shrub stratum is diverse and relatively dense, but the herbaceous stratum is usually less dense than the shrub stratum in the aspen communities. Douglas-fir usually has a closed canopy and a well-developed shrub layer. The herbaceous layer is poorly developed and consists mostly of grasses.

Producer organisms within the aspen-Douglas-fir communities provide a diverse habitat for consumer organisms. Harsh climatological conditions in winter, however, limit the year-round abundance and diversity of animal species. Elk and feral horses utilize nutrient sources in these communities year-round, but deer cannot use the area during winter because of deep snows. Cattle forage along the periphery of the aspen stands but do not penetrate them deeply.

Only five species of small mammals occur within the aspen-Douglas-fir communities in the study area. The red-backed vole is the most prominent small mammal, and porcupines also utilize these communities. Bird density and diversity are relatively high in these communities, especially within the Douglas-fir segment.

b. Upland Meadow Community Interactions - Upland meadow communities are found on windswept, west-facing slopes at upper elevations (2,270 to 2,685 m) where soils are shallow and rocky. Plant species which comprise the community include perennial forbs and grasses, with a conspicuous absence of trees. Harsh environmental conditions (direct exposure to prevailing winds which create high evaporation rates, reduced precipitation input, increased erosion, and physical disturbance to rooted plants, and lower temperatures) in these areas select for plants that are low growing, wind resistent, and not easily desiccated. Plants adapted to these areas help reduce erosion and evaporation rates. Competition for water is important. Shrub species are rare in these areas, and those occurring are low-growing forms. Shrub species include rabbitbrush and horsebrush. The herbaceous stratum is highly diverse (60 species) and forms a carpet-like mat over much of the area which helps reduce evaporation and erosion created by strong winds.

Deer mice, least chipmunks, and two species of voles are among the small mammals found in these communities. Few bird species occupy these areas, but cattle, deer, and feral horses utilize them heavily for forage. This heavy utilization is partially related to use by feral horses in the winter, when exposed forage on these windswept sites is the most readily accessible food source. Heavy utilization of upland meadow communities by consumers appears to be depleting the vigor of these communities.

c. Greasewood Community Interactions - Greasewood communities are found in low-lying areas with high alkalinities where the water table is at or near the soil surface. The alkalinity of the soil appears to be the most important factor contributing to the distribution of this species. Relatively low soil alkalinities within greasewood communities are marked by the presence of rabbitbrush and big sagebrush, but as these chemicals increase in concentration, greasewood takes over and rabbitbrush and sagebrush disappear. Concentration of salts by greasewood plant tissue and subsequent deposition in the soil further contributes to soil characteristics preferred by greasewood. Understory is often completely absent or very sparse in these communities.

Greasewood communities in association with sagebrush support relatively large

numbers of small mammal species. This is largely due to the availability of shrub cover. This association also supports relatively large numbers of bird and bird species; but, greasewood probably does not serve as important nutrient sources for large herbivorous mammals.

d. Riparian Community Interactions - Riparian communities occur in open bottomlands near springs, along the bottom of steep draws which are fed by springs and seeps, and along drainageways of intermittent streams. The interaction between terrestrial and aquatic components of the ecosystem is more pronounced in these communities than elsewhere in the study area.

The most important abiotic factor which contributes to formation of riparian communities is water. Plant species which comprise this community type include cottonwood, aspen, big sagebrush, rubber rabbitbrush, quackgrass, bluegrasses, and dandelion. These species are dependent on availability of abundant moisture. Shrub cover ranges from low (2%) to moderate (25%). The herbaceous layer is dense with cover values as high as 80%, which reflects moist growing conditions. These areas are grazed by cattle and feral horses, and are used as watering holes for larger mammals, birds, bats, and invertebrates. Amphibians, shore birds, and waterfowl are highly dependent on available water and habitat associated with these communities.

Several small mammal species utilize the area, and bird diversities and densities are higher there than in any other community type. The high bird populations reflect the availability of water and the abundance of food, including a variety of terrestrial and aquatic plants and terrestrial and aquatic invertebrates. The limited amount of surface water available in the area enhances the importance of the riparian communities, especially as they relate to the overall ecosystem.

B. Aquatic Interactions - In the past, aquatic ecosystems were defined as microcosms. The microcosmic view arose because aquatic organisms were studied apart from their physical environment rather than in relationship to it. Today, aquatic systems are viewed in relationship to surrounding terrestrial components. Stream biology cannot be understood without considering influences

of the entire drainage, for a stream is a continuum of water and life which changes not only according to seasonal fluctuations but also according to distance downstream. The maturation and interaction of a stream system from its headwaters downstream to where it becomes a mature stream community are depicted in Figure 3-14-5. The importance of terrestrial components to the dynamics of this system can be seen from this diagram.

The Tract C-a aquatic ecosystem lies within the Piceance Creek hydrologic basin. There are no permanently flowing streams on the tract, but parts of Corral Gulch and Yellow Creek which drain the area, and the White River, flow year-round. Ephemeral or intermittently flowing streams within the basin and on Tract C-a sustain flows only during periods of snowmelt and run-off from thunderstorms.

Average mean annual precipitation for the basin area ranges from 17.8 to 61.0 cm per year, with nearly one-half of the precipitation falling as snow. In addition to these ephemeral streams, there are approximately 30 springs and seepages supplied by groundwater within an 8.0-km radius of the tract. Many of these springs and seeps flow year-round, but volume of flow varies greatly with season.

Basin runoff to the White River is estimated to be 19.3×10^6 m^3 per year from Piceance and Yellow Creek. Eighty percent of the runoff is derived from groundwater discharge and 20 percent directly from precipitation runoff. The annual discharge of Yellow Creek is estimated at 16.0×10^5 m^3 per year.

The aquatic systems in the study area affect the immediate terrestrial environment by providing water for development of the willow, bullrush, and tamarisk communities. Some terrestrial plant and animal species are supported by these aquatic habitats. Interactions between the aquatic system and the terrestrial system are not dramatic because of the semi-arid nature of the area, the limited extent of the riparian habitats, and the adaptations of the components of the terrestrial system which provide for survival with limited moisture.

1. Abiotic-Biotic Interactions - As previously mentioned in the terrestrial interactions section, there are abiotic factors which limit extent and

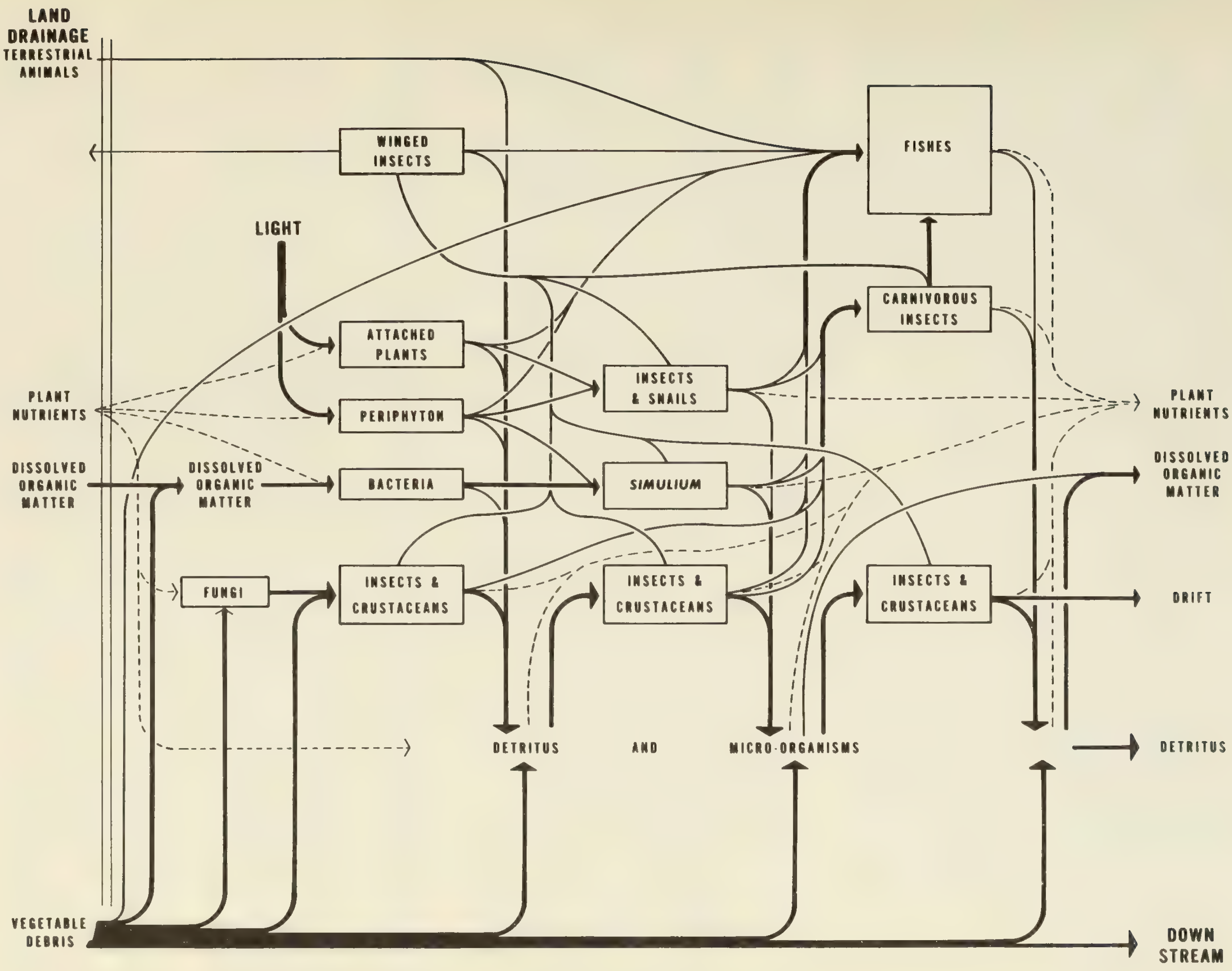

Figure 3-14-5

DIAGRAMMATIC REPRESENTATION OF THE TROPHIC RELATIONSHIPS OF THE RITHRON ECOSYSTEM -- DOTTED LINES REPRESENT SALTS IN SOLUTION, (Source: Hynes, 1970)

diversity of ecosystems. This concept also applies to aquatic systems. Abiotic phenomena which can potentially influence magnitude and direction of system development are numerous. Many locations within the aquatic system are unique enough to be considered different habitat types. However, certain similarities such as type of substrate, flow frequency, flow velocity, or physical and chemical properties of the water can be used to group these areas into the following habitat types:

- spring brooks
- pools and marshy areas
- back channel/slack water area
- riffle areas

Spring brooks are intermittently or constantly flowing habitats with gravel, sand, and/or shale substrates. Other similarities of these stations are typically cold, constant water temperatures, shallow depths (<18 cm), and paucity of macrophytes (rooted aquatic vegetation).

Areas described as pools and/or marshy habitats are slow-flowing areas with detrital covered substrates. They are also relatively shallow (from 30 to 90 cm), support fairly good populations of aquatic macrophytes, and contain water year-round.

Back channel/slack water areas are constantly flowing water habitats in which the rate of flow is relatively slow and depths may exceed 1 m. These areas generally have either compacted gravel and fine sand substrates or gravel and cobble substrates. Some may also contain substantial quantities of silt. Gravel and cobble substrates in these areas are not well consolidated and result in frequent displacement of benthic or epiphytic organisms.

The areas defined as riffle habitats in this study occur only in the White River. These areas are fast flowing and generally have a cobble and boulder substrate which provides good habitat for bottom fauna. The depth of these areas varies widely with seasonal flow.

The influences of abiotic components on aquatic ecosystems are substantial.

a. Substrate Type - A factor which influences spatial distribution and diversity of organisms in a stream system is substrate type, a reflection of the composition of the drainage area (sand, shale, or rubble). The diversity of substrate type provides a wide variety of microhabitats, and aquatic organisms have developed specialized adaptations to fill these microhabitats.

There are four basic substrate types within the study area:

- Silt
- Fine sand
- Gravel to cobbles
- Boulders

Organisms commonly found in association with silt substrates are midges (chironomids) and flies (dipterans), worms (oligochaetes), periphyton, and snails. Midges, flies, and worms are also associated with fine sand substrates. Cobble and boulder substrates frequently support caddis flies, mayflies, stoneflies, and periphyton. Substrates composed of boulders support periphytic algal growth, caddis flies, mayflies, stoneflies, and other benthic organisms. Under favorable water conditions, stable boulder substrates also produce important habitats for fish populations. The stability inherently associated with boulder substrates is largely responsible for increased species diversity.

b. Velocity of Flow - Velocity of flow affects the biotic components of the aquatic ecosystem in several ways. The most important effect of flow is its role in determining the nature of the substrate which, in turn, influences the biotic components. Fine silts and sands are carried from certain areas of streams by rapidly moving waters. When these waters are slowed by a leveling off of the stream gradient or by physical obstructions, they deposit their sediment loads. Consequently, compacted sand and gravel substrates covered by silt are common to standing or slack water areas, while cobble and boulder substrates are associated with more rapidly moving water near the stream channel.

Velocity of flow at the headwater and tract stations generally ranges from 30 to 90 cm/sec during late spring to <3 to 45 cm/sec in late summer. Flow velocity in the White River generally ranges from 120 to 182 cm/sec in late spring to 60 to 90 cm/sec in late summer.

The stability of the substrate is important in respect to disturbances of the biotic community. When water velocity is rapid, unstable substrates can be scoured and some aquatic organisms including periphyton and higher aquatic plants can be displaced. Many macro-invertebrates are specially adapted to survive in stream situations. They may have special appendages for attachment (hooks, suckers), or streamlined bodies. Also, some fishes found in rapidly flowing streams have special anatomical adaptations and modified breeding and feeding habits which allow them to succeed in these situations.

c. Permanency of Flow - Permanency of flow is of vital importance to aquatic dwelling organisms. In semi-arid regions, this can be highly variable because it depends on local climate, annual precipitation, snowmelt, groundwater runoff, soil type, and evaporation. In the study area, rainfall is highly variable and accounts for about one-half of the annual precipitation. Thunderstorms occur infrequently, but when they do they may be violent and produce flash floods which physically disrupt aquatic communities.

Many of the stream beds in the area are composed of porous alluvial deposits which permit easy percolation and loss of water from the stream into subsurface formations. Surface water which does remain in the stream may readily evaporate in the semi-arid climate. As a result, many streams become intermittent in nature, flowing only during spring snowmelt or after a thunderstorm. Aquatic organisms which populate these intermittent streams have adapted to periods of drought by various means such as becoming dormant or burying at times of extremely low flow, then rapidly becoming active during periods of water availability.

d. Physical and Chemical Characteristics - Waters sampled during the RBOSP Aquatic Baseline Studies ranged from hard to very hard. All contained both carbonate and non-carbonate hardness. In Yellow Creek, magnesium

occurred in greater concentrations than calcium (major contributors to carbonate hardness). The concentration of dissolved solids (carbonates, sulfates, and chlorides) was relatively high in all areas, but particularly so in Yellow Creek. Suspended solids concentrations were generally highest in the spring brooks on or near Tract C-a and lowest in the headwater spring brooks and pond habitats. Waters of the tract and Yellow Creek spring brooks generally carried the greatest quantities of organic carbon. Waters in the tract area also contained relatively large quantities of organic nitrogen. The higher quantities of organic matter in waters on or near the tract and in Yellow Creek are likely due to greater contributuions of allochthonous (from the drainage basin) organic material from nearby terrestrial plant communities or grazing livestock. Inorganic plant nutrients, particularly nitrogen and phosphorus, were usually found in concentrations greater than those considered limiting for the growth of algae and were often at levels considered enriching.

Of all the aquatic habitats included in the Aquatic Baseline Studies, the two Yellow Creek habitats (pond and spring brook) had the harshest chemical conditions. In the spring brook habitat near the confluence of the White River and Yellow Creek, both sodium and chloride concentrations approached upper tolerance limits for freshwater fish. A pond habitat far downstream on Yellow Creek generally had lower water temperatures and lower concentrations of sodium, chloride, and dissolved solids, but higher concentrations of sulfate and hardness than the Yellow Creek spring brook stations.

2. Biotic Interactions - Streams are basically heterotrophic, deriving most of their energy in the form of organic matter from the drainage area rather than producing the majority of the organic matter by internal primary production.

a. Primary Producer Interactions - The major source of autochthonous (in the stream) primary production in the study area is periphyton. These organisms which firmly attach to a substrate are photosynthetic, utilizing light, nutrients, water, carbon dioxide, and chlorophyll to produce simple sugars which are subsequently converted to plant tissue. Periphyton production is controlled by water temperature, light intensity,

current, substrate, alkalinity, and presence of minerals.

Standing crops of periphyton tend to be greatest in White River riffle habitats and lowest in headwater tract station brook habitats. In the alkaline spring brook habitats of the headwaters and tract areas, diatoms comprise the dominant algal group of periphyton. Densities of periphyton in the pond habitat tend to be similar to those at the Yellow Creek spring brook habitats although the species composition is different. Organisms which feed directly upon periphyton include some aquatic insects, snails, and some fish.

Macrophytes, or larger aquatic plants, contribute very little to the autochthonous primary production of the aquatic ecosystems in the study area. In the two ponds of the tract and headwater stations, aquatic macrophytes contribute somewhat to the autochthonous organic material; however, little of this plant material is used by primary consumers, and most of it is utilized by decomposers.

Phytoplankton (floating algae) constitutes a secondary source of autochthonous primary production for all four habitat types in the study area. Composition and species abundance of phytoplankton of the alkaline spring brook habitats of the headwater and tract station indicate that phytoplankton is primarily recruited from periphyton. Low phytoplankton abundance at these locations demonstrates that phytoplankton is of secondary importance to periphyton in terms of autochthonous primary production.

Species composition and abundance of phytoplankton in the White River are generally different from that of headwater, tract, or Yellow Creek spring brook habitats. Phytoplankton of the White River riffle and slack water habitats contains a mixture of algae derived from both periphytic and planktonic species. In general, phytoplankton abundance is highest during the spring in the White River, but never higher than phytoplankton abundance of Yellow Creek.

b. Consumer Interactions - Consumers are also called secondary producers since they function in the energy cycle as a transfer point between

primary producers and higher order consumers. At the consumer level, the situation in streams becomes extemely complex because most taxonomic groups of aquatic animals have at least some forms feeding directly on primary producers and others feeding on secondary producers (primary consumers). Moreover, many organisms are capable of feeding on more than one level in the food chain. This may vary seasonally or throughout the life cycle. The relationship, therefore, between producers and consumers becomes a complex food web.

Primary producers serve as a food source for many microcrustacean organisms such as Alona and Pleuroxus which commonly graze on periphytic organisms on rocky substrates and macrophytes in the slack water areas. In addition to feeding on the primary producers, the microcrustacea also utilize detritus washed in from the drainage area. Some microcrustacea are true planktonic forms feeding on phytoplankton. Microcrustacea reach their peak abundancies in permanent water areas during the summer months. Rotifers, also an important group present on tract, feed primarily on the phytoplanktonic algae. However, both the rotifers and microcrustacea have carnivorous forms which feed on other rotifers and microcrustacea. These forms act as secondary consumers.

The predominant organisms most characteristic of streams are the benthic forms which are adapted to living on or in the stream substrates. Some feed on detritus such as the aquatic worms (Naididae and Enchytraeidae) in silty sediments. The blackfly larvae (Simuliidae) feed on organic matter they catch floating downstream and are specially adapted for this feeding habit. Others such as the midges (Chironomini and Tanypodini) are carnivorous, feeding on other benthic forms. The beetles (Dytiscidae) and bugs (Corixidae) have a variety of feeding habits but are often carnivorous, feeding on plankton.

Fish occupy the highest trophic levels in the aquatic ecosystem, but none are present on tract. In the White River, there are populations of carp, channel catfish, red shiner, and flannelmouth suckers.

Fish are largely opportunistic feeders and will take whatever is most abundant from mayflies, stoneflies, caddis flies, midges, worms, etc. Local fish

distribution is largely controlled by the available food which, in turn, is controlled by drainage basin events.

c. Decomposer Interactions - Bacteria and fungi are important components of the energy system. Decay of dead plant material seems to at least be initiated by these organisms. The decomposer organisms causing decay take up a great deal of nitrogen from the water and convert it to protein. In this way the carbohydrate energy of the dead plant material is converted to more suitable food for animals. The microcrustacea, rotifers, and some benthic organisms such as the Simuliidae make direct use of suspended bacteria, thus closing the nutrient and energy cycles.

14.4 SUMMARY

Terrestrial and aquatic community interactions are described with respect to some of the major biotic and abiotic components involved in these interactions. Ecological interactions are not confined to community boundaries; they integrate between communities and between terrestrial and aquatic systems.

On the study area, sagebrush, pinyon-juniper, and mixed brush communities can be defined but, in each case, transition zones between each type can also be identified. These transition zones represent overlapping environmental conditions which favor neither community but can sustain mixtures of both. Frequently these transition zones produce greater ecological diversity (and interactions) than do "pure" communities. In the more shallow arid soils of the surrounding ridge tops, pinyon-juniper is the dominant vegetation type. Although there is distinct zonation between sagebrush and pinyon-juniper in some cases, the typical case is a gradual transition where soil depth does not vary sharply. In these areas, big sagebrush is often a component of the pinyon-juniper understory; however, as the canopy thickens and litter accumulates, big sagebrush often disappears in the pinyon-juniper understory. Where the pinyon-juniper community has been subjected to fire, grasses and herbaceous species have invaded the area and, in later stages, have been followed by sagebrush and/or rabbitbrush, depending on the elevation and alkalinity of the soils.

Ultimately, pinyon-juniper may re-establish itself in burned-over areas. If grazing is heavy during early stages of revegetation in burned-over areas, pinyon-juniper may be prevented from reinvading the area because of the destruction of young shoots.

In the higher elevational reaches of the study area, sagebrush and mixed brush communities intermix. Both communities thrive in deep soils (mollisols); however, mixed brush (especially Gambel oak) requires more soil moisture than sagebrush. Despite their common soil requirements, there are few distinct transition zones between these two communities in the study area. In fact, one of the upland sagebrush associations supports Utah serviceberry and mountain snowberry in its shrub stratum.

This association ranges from the fairly smooth terrain of 84 Mesa to steep slopes below the summit of Cathedral Bluffs west of Tract C-a. These high elevational sagebrush-mixed brush communities provide a patchwork effect when viewed from the air.

Intergrading of pinyon-juniper and mixed brush appears to be closely related to soil type and elevation. Pinyon-juniper is found on shallow, arid soils and on shale outcroppings where soil moisture is limited, whereas mixed brush requires deeper soils and increased moisture availability. In addition, pinyon-juniper elevational range is between 1,850 to 2,300 m as opposed to mixed brush, which is more restricted in elevation (2,150 to 2,485 m). The increase in precipitation with elevation primarily accounts for the distribution of these communities.

Productivity of the three major terrestrial community types ranges from 105 kg/ha in pinyon-juniper communities to 271 kg/ha for mixed brush, with sagebrush averaging 210 kg/ha. Browse utilization in these areas ranges from 7% on sagebrush sites, 24% on pinyon-juniper sites, to 44% on mixed brush. Low productivity is associated with heavy use in the mixed brush and pinyon-juniper community. Heavy grazing causes constant shifts in animal species composition and abundance in these communities. Eventually this affects other communities as well. Reduction of the herbaceous vegetation due to heavy

grazing, fire, or other factors will result in a change in plant species composition, followed by a change in animal species distribution and abundance. Reduction of the herbaceous layer could also affect the character of the soil substrate and influence erosion potential. This is important to adjacent aquatic communities because the stream valley interacts with the stream in every respect. The geologic strata of a region determines availability of ions, soil characteristics, and topography. Soil and climate determine vegetation, and vegetation controls the supply of organic matter. Organic matter reacts with soil to control the release of ions. Compounds, particularly nitrogens and carbons, control decomposer organisms and decay of litter and, hence, lie right at the foot of the food cycle. The dynamics of the aquatic system are related to this complex set of interactions between climate, soils, topography, and terrestrial plant and animal communities.

Although dynamics of the aquatic system are largely controlled by its entire valley, interactive feedback from the stream to the terrestrial system also occurs. On the microscale, both the stream and the terrestrial system are astoundingly complex sets of ecosystem interactions. However, the interactions can be generalized with a good degree of confidence from basic ecological principles.

The importance of baseline studies and the consideration of ecological relationships between abiotic and biotic factors lies in the realm of predictive ecology. Predicting ecological effects of natural or man-made events has important ramifications for those who must make the decisions concerning future development. Information gained in the second year of baseline studies on Tract C-a will be used to further characterize the ecological relationships of the area, in the attempt to identify the long-term effects of development. A variety of statistical procedures will be used to analyze the cumulative baseline data after 2 years of study to further characterize the aquatic and terrestrial ecosystems in the study area. These analyses are listed in Table 3-14-3. The conceptual frameworks around which these analyses will be oriented are presented in Figures 3-14-6 and 3-14-7.

Table 3-14-3

ENVISIONED STATISTICAL PROCEDURES FOR ANALYSIS OF SELECTED PARAMETERS FOR EXAMINATION OF TERRESTRIAL AND AQUATIC ECOSYSTEMS INTERACTIONS

	STATISTICAL PROCEDURES							
Comparison	Linear Regression	Non-Linear Regression	Correlation	Analysis of Variance	Analysis of Covariance	Multivariant Analysis	Ordination	Non-Parametric Methods
Vegetation								
Soil Depth	X	X	X	X	X	X	X	
Soil Texture	X	X	X	X	X	X	X	
Chemical Nutrients	X	X	X	X	X	X	X	
Duration of Snow Cover								X
Precipitation	X	X	X	X	X	X	X	
Solar Radiation	X	X	X	X	X	X	X	
Animal								
Plant Species Composition	X	X	X		X	X	X	X
Plant Phenology	X	X	X		X	X	X	X
Vegetation Cover	X	X	X		X	X	X	X
Vegetation Height	X	X	X		X	X	X	X
Plant Litter Toxicity								X
Vegetation Toxicity								X
Aquatic Biota								
Texture of Substrate	X	X	X		X	X	X	X
Water Chemistry	X	X	X		X	X	X	X
Water Temperature	X	X	X		X	X	X	X
Duration of Water Body	X	X	X		X	X	X	X
Rate of Flow	X	X	X		X	X	X	X
Depth	X	X	X		X	X	X	X

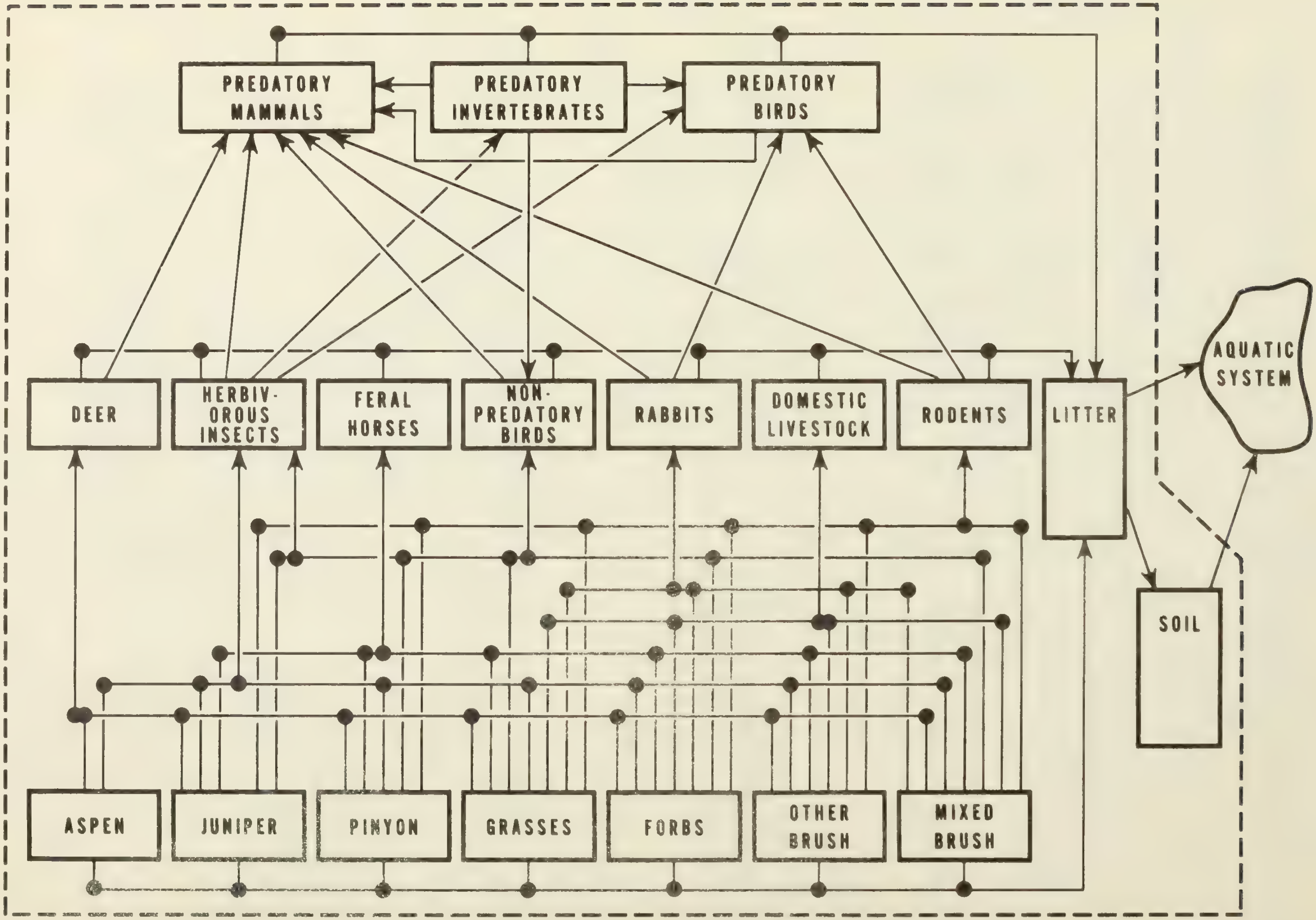

Figure 3-14-6
BLOCK OF A CONCEPTUAL FRAMEWORK FOR THE TERRESTRIAL ECOSYSTEM ON TRACT C-a

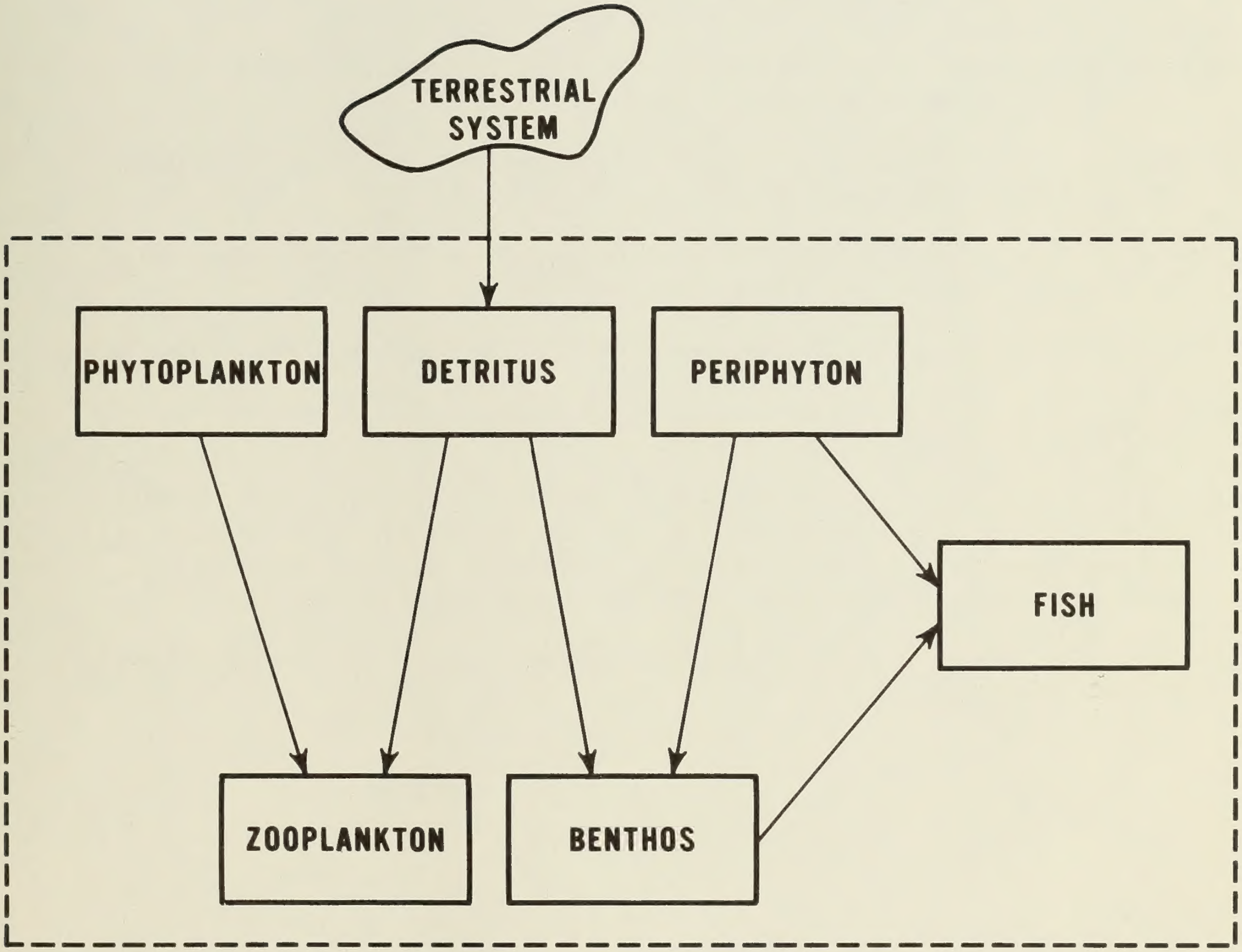

Figure 3-14-7

A BLOCK DIAGRAM OF THE CONCEPTUAL FRAMEWORK FOR THE AQUATIC SYSTEM ON TRACT C-a AND THE WHITE RIVER.

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